metal progress

Metal Progress

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Cover by DOUGLAS RADER from illustrations of forging operations at A. Finkl & Sons Co.

Recent Accidents With Large Forgings, by E. E. Thum 49

A daylong discussion of the causes of four failures of massive rotor forgings reveals that two were due to unduly high stress concentrations introduced by the design or by a repair, and two others were due to misinterpreting or minimizing the evidence of internal defects found by ultrasonic inspection. (S 21, ST)*

Service Failures of Aluminum Die-Casting Dies, by G. A. Roberts and A. H. Grobe 58

The three most common types of failures of aluminum die-casting dies are heat checking, pitting and impingement soldering. Causes of each are investigated. (S 21, E 13, TS)

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The new A.I.S.I. Types 201 and 202 are excellent for many structural applications in corrosive environments. A modified alloy with more chromium and nickel may be necessary to resist the more severe applications in the chemical industry. (SS)

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METAL PROGRESS is published monthly by the AMERICAN SOCIETY FOR METALS. Publication office, Mt. Morris, Ill. Editorial, executive and advertising offices, 7301 Euclid Ave., Cleveland 3, Ohio. Subscription \$7.50 a year in U.S. and Canada; foreign \$10.50. Single copies \$1.50; special issues \$3.00. . . . THE AMERICAN SOCIETY FOR METALS is not responsible for statements or opinions printed in this publication. . . . Requests for change in address should include *old* address of the subscriber; missing numbers due to "change of address" cannot be replaced. Claims for nondelivery must be made within 60 days of date of issue. No claims allowed for overseas subscribers. Entered as second-class matter at the Post Office in Mt. Morris, Ill.

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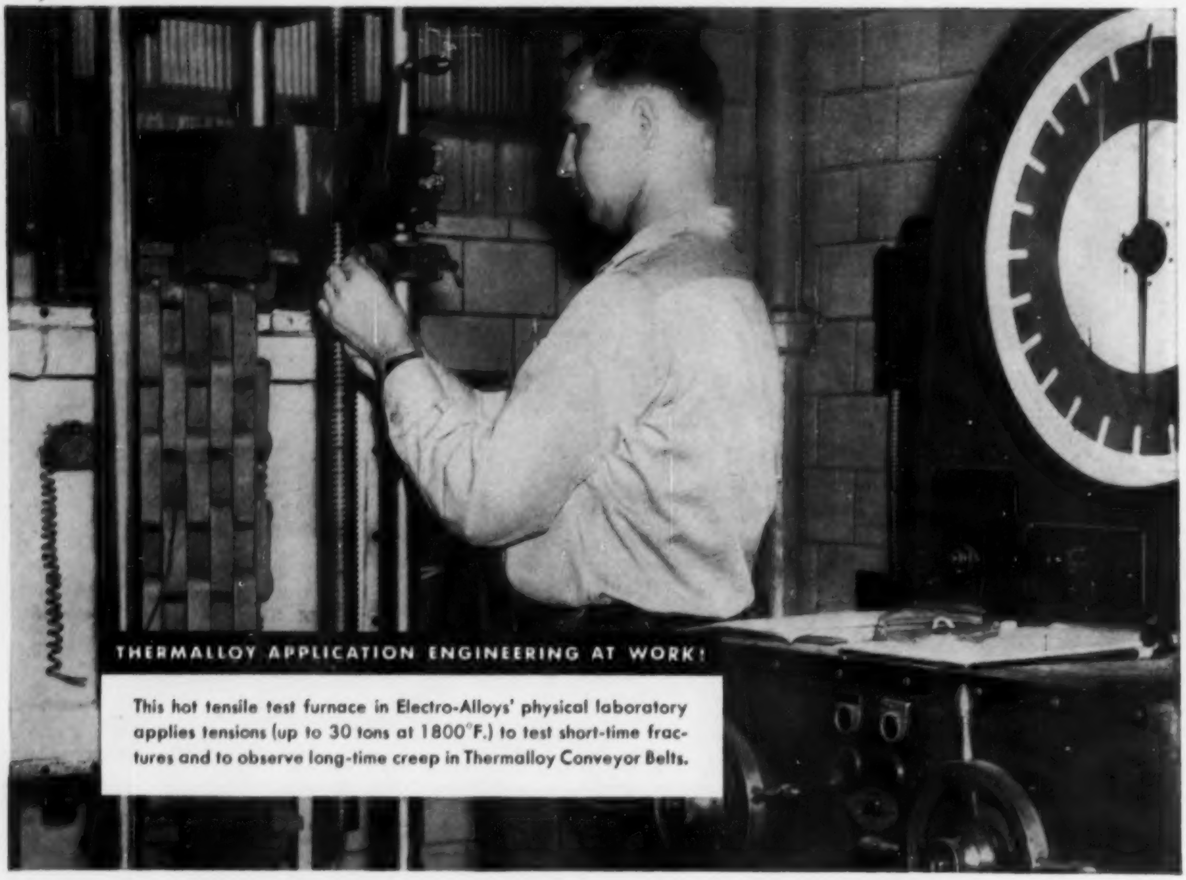


THERMALLOY APPLICATION ENGINEERING AT WORK!

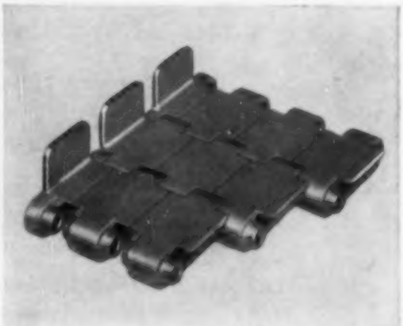
This hot tensile test furnace in Electro-Alloys' physical laboratory applies tensions (up to 30 tons at 1800°F.) to test short-time fractures and to observe long-time creep in Thermalloy Conveyor Belts.

A miniature furnace to test theories!

Service life of a heat-treating furnace conveyor belt may be affected by so many variables, i.e. uneven loading, misalignment, temperature differentials, etc., that proper design, highest quality and the right material are of utmost importance.

At Electro-Alloys, a staff of engineers and metallurgists are constantly studying these factors in the physical testing laboratory shown above. A hot tensile test furnace is continually in use subjecting Thermalloy* conveyor belts to various combinations of loading and temperature. In this way, design theories developed by our engineers are tested and highest possible quality standards are maintained to insure production of furnace conveyor belts that will be the ultimate in trouble-free operation.

Electro-Alloys also applies engineering and metallurgical know-how in the production of heat-resistant Thermalloy castings for other furnace parts such as sprockets, idlers, skid rails or rollers, crossbeams, wall boxes and radiant tube assemblies. For complete information, call our nearest representative or write for Thermalloy Conveyor Belt Bulletin T-241, Electro-Alloys Division, 7002 Taylor St., Elyria, Ohio.



To meet extra-severe operating conditions, a Thermalloy Heavy-Duty Conveyor Belt was developed. This partially assembled belt shows the short integral cast pins that eliminate "crank-shafting."

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
Elyria, Ohio

*Reg. U. S. Pat. Off.

Conversion Coatings for Cadmium and Zinc, by Edward F. Foley, Jr. 86
Economical and versatile finishes for cadmium and zinc-plated parts and zinc-base die castings. With minor modifications in processing conditions, a wide range of surface finishes can be obtained. No expensive equipment is required. (L 14, Cd, Zn)

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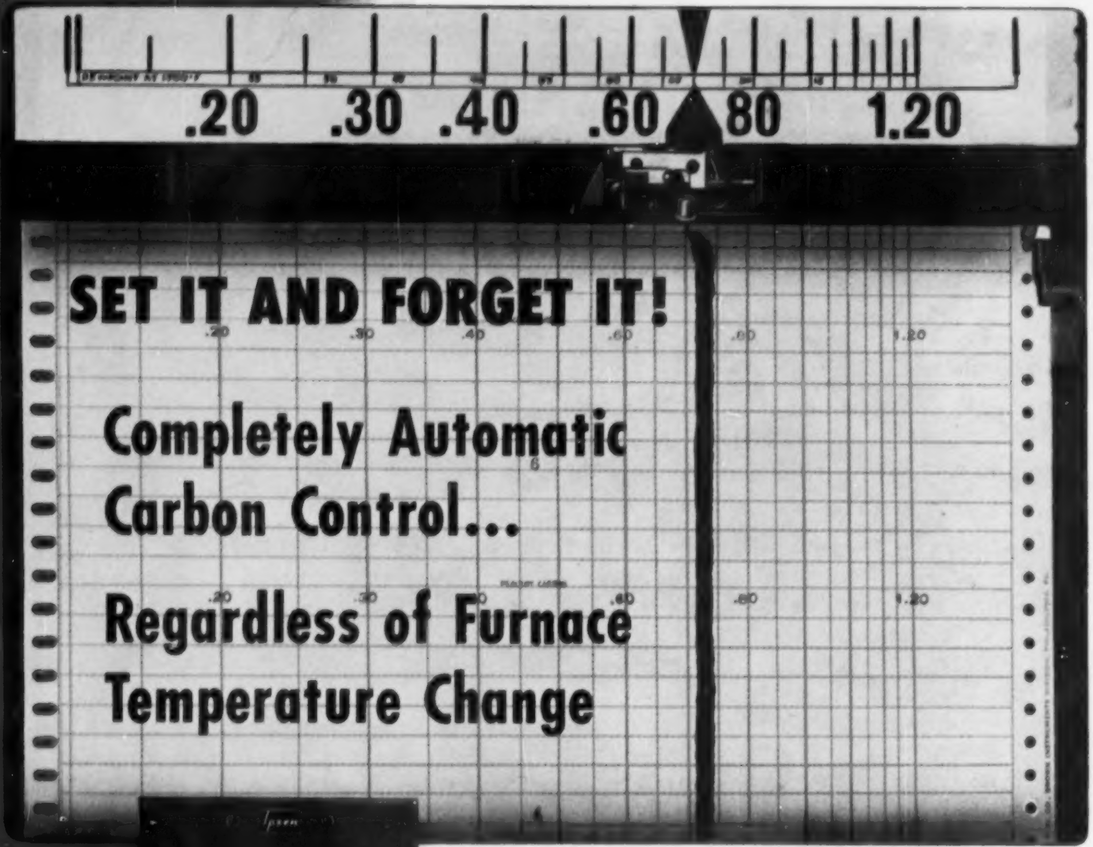


The CARBOTRONIK is a self-contained unit and can be placed at any distance from the furnace or generator being controlled. It records and indicates directly in percent carbon.

The Ipsen CARBOTRONIK carbon controller automatically coordinates furnace temperature and dew point to continuously provide any desired carbon potential from 0.20% to 1.25%. Enriching gas additions are made at the furnace and accuracy is ± 0.02% carbon over a range of 1400° F to 2000° F.

Dew points are measured every 5 seconds by a voltage type element. This sensing element is unaffected by ammonia or any other atmosphere gas and it does not require calibration. The operator merely sets the selector to desired carbon content and any furnace temperature changes are compensated for automatically.

IPSEN INDUSTRIES, INC.
717 South Main Street, Rockford, Illinois

AUTOMATIC **Ipsen** HEAT TREATING UNITS

As I was saying...

It's wonderful out here in the Great American Desert, where I am spending my annual holiday. The sun shines brightly and we lunch on the front porch or the patio or the sundeck and watch carefully that the sun does not cook us. But I'm a restless guy and must have news from headquarters every once in a spell, so Evelyn sends me frequent messages. Perhaps you are interested:

"Dear Boss: It's cold. The snow is falling fast and furiously and it was ten above zero last night. Thank your stars you are missing it. Many Christmas cards are coming in, and I am sending them to you separately.

"Mr. Thum is upset because the printer lost the copy for the double-crostic he made up and is mailing as a Christmas greeting card. He thinks the printer got so interested in solving it that he forgot to have the type set. He is busy on the A.S.M.-A.E.C. book on Powder Metallurgy going to the printer soon; also working with the Cleveland Art Institute to develop and select M.P. covers for next year. We had a letter from a member stating that M.P. covers are the tip-top covers of any trade or association publication.

"Mr. Bayless sure has his hands full and his desk also; he just received a wagon-load of galley proofs of *Transactions* material to proof-read and page. *Transactions* is on schedule. Orders from the members are coming in with every delivery, and more than 7,000 copies of *Transactions* have been requested; more than 2,300 other books published by the A.S.M. have also been ordered. Copy for the seminar book, "Theory of Alloy Phases," has been received and he is getting it to the printer pronto.

"Mr. Wells has been busy answering wires, telephones and letters requesting space for the 38th National Metal Exposition to be held in Cleveland Public Auditorium, Oct. 8 to 12, 1956. The total amount of space requested is sensational, or as you would say 'mastodonic'.

"He is getting out the billing for dues to be mailed Feb. 1 for membership expiring March 1. About 50% of the dues come up for payment March 1.

"Mr. Lyman had the Handbook Committee in for a meeting. All but two showed up. He reports a fine constructive session with lots accomplished. Many new subcommittees were selected and big plans discussed for a new edition of the A.S.M. Handbook.

"Mr. Ford has been on the go. With new M.P. representatives in Philadelphia, Pittsburgh, Chicago, and the new Detroit office, he has been spending his time in the field. Reports many contracts, new and renewed, have been received. The list has been sent to you.

"Mr. Brasunas's mail has been heavy. Many new chapters in the study courses are being received from the authors and a number of courses have been completed and are now undergoing review before going into production. Many letters making inquiry about when and how the correspondence courses will be available. He said yesterday he hopes to have some of the courses ready in three or four months.

"The real estate firm that was engaged to locate additional sites for the A.S.M. Metal Science Center advised the staff committee that they are on the job and will report as soon as the survey is complete. Proctor Noyes, chairman of the Cuyahoga County Planning Commission, phoned yesterday that he is proceeding with the work requested by the A.S.M. Board to determine the adaptability for a Metal Science Center of the two sites considered at the November meeting.

"Marjorie Hyslop says the booklets for the Second World Metallurgical Congress (Chicago 1957), together with the letter to the ambassadors of the free countries of the world to participate, are to be mailed about Jan. 20. She says the list of government officials and technical societies numbers close to 8000. I'll bet (not too much) that the Second W.M.C. will have twice as many overseas conferees (1100) as the First (550).

"We are all busy. It's so cold that is the only way we can keep warm. Have a good rest. EVELYN"

Thanks, Evelyn, for the information. I am passing it on. I stewed about what to print in this column this month. Your letter was a lifesaver!

Cordially,

Bill

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS

These turboprop propeller blades

Model CT634S of the Curtiss-Wright Turbolectric series was the first U. S.-designed and built turboprop propeller to be certificated for commercial use by the Civil Aeronautics Administration. This model and others are already in quantity production for military aircraft.

Turbolectric propellers use extruded hollow steel blades produced by the controlled extrusion process developed by Curtiss-Wright. The extruded blade begins as a single-piece alloy steel billet.

With the development of this propeller and the controlled extrusion process came the need to select the right alloy steel. And here's where teamwork paid off.

Republic metallurgists, working closely with Curtiss-Wright metallurgists and engineers, selected an alloy steel with the following properties that make the extrusion process successful from both a production and cost standpoint: freedom from imperfections, uniform response to heat treatment, workability in all stages, weldability, bendability—hot or cold.

These properties in combination with the extrusion process give:

(1) IMPROVED STRENGTH-WEIGHT RATIO. The tough, integral structure of the extruded alloy steel blade provides greater strength and resistance to fatigue with minimum weight.

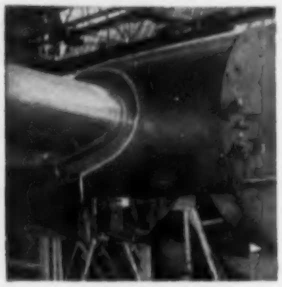
(2) IMPROVED QUALITY. Greater uniformity is assured by fabricating from a single homogeneous material.

(3) INCREASED PRODUCTION. The number of manufacturing operations is reduced. Production per hour is increased. Floor space is saved.

(4) REDUCED COST. Less steel for original stock, less machining, and lower cost tooling and equipment are required. Expensive welding and accompanying preheating and post-heating operations, as well as milling operations, have been reduced.

What about your product? Are you using the right steel in the right place? Republic—world's largest producer of alloy and stainless steels—offers you the services of experienced field metallurgists who will work with your staff in determining where these versatile steels can effect the greatest savings. Just send us the coupon.

Strength-to-Weight or Heat Problems—Republic Has the Answers



◀**TITANIUM SAVES WEIGHT ON DC-7** with no sacrifice in strength or safety. Republic is an old hand at this high strength-to-weight business. We pioneered the use of alloy steels, then stainless steels—followed by high strength steels. Now come Republic Titanium and Titanium Alloys. Years of experience gained in helping hundreds of manufacturers design and re-design their products to get more strength with less weight are available to you.

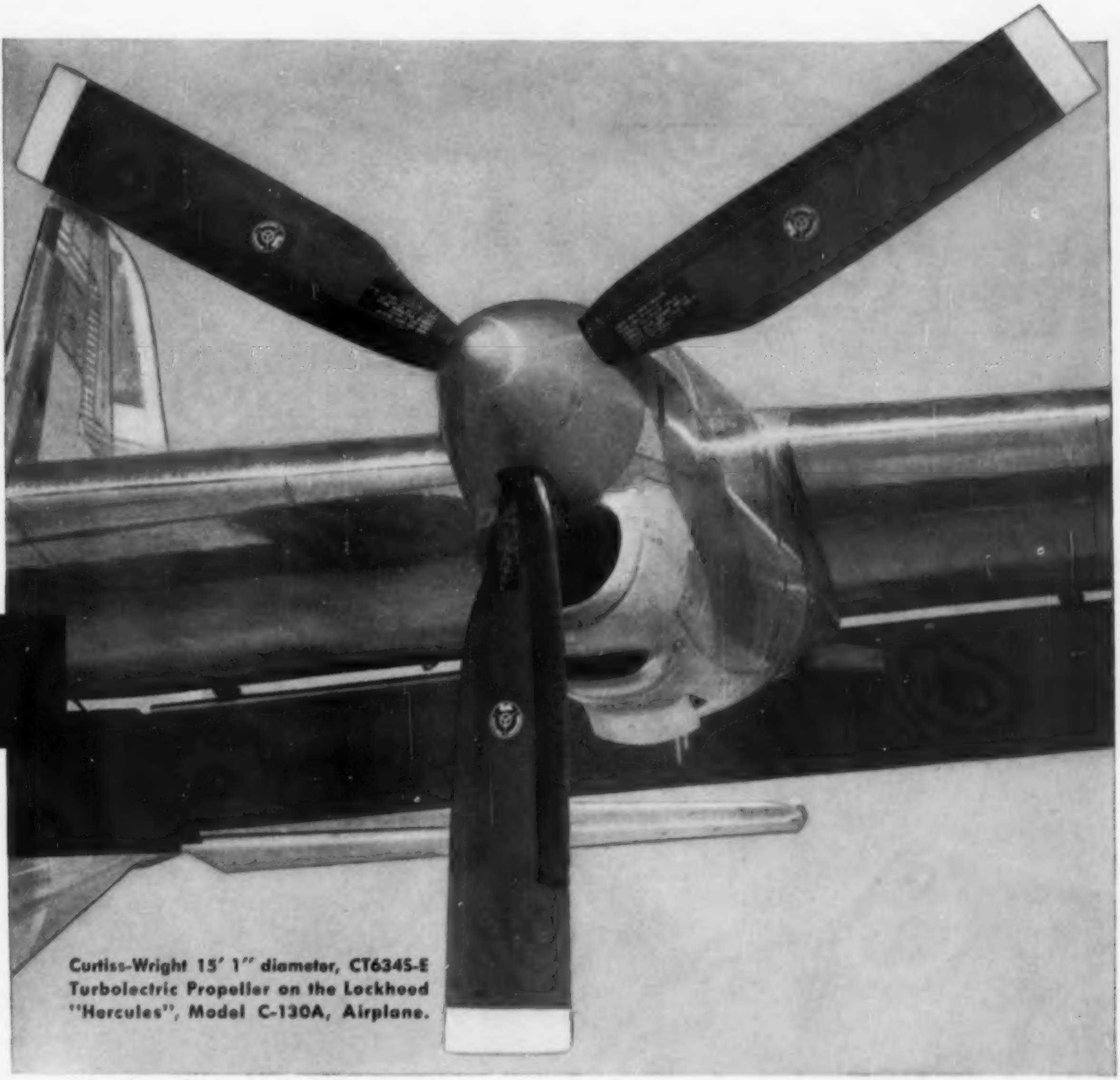
600° F TEMPERATURE HAS LITTLE EFFECT ON DE-ICER DUCTS made of Republic▶ ENDURO Stainless Steel. Because of its extremely high strength-to-weight ratio, and corrosion-resistance you can use ENDURO in thinner, lighter sections. It resists temperature extremes, holding its strength, toughness, and shock-resistance all the way from blistering heat through sub-zero cold. Republic produces ENDURO® in all commercial forms.

REPUBLIC

REPUBLIC STEEL ®

World's Widest Range of Standard Steels

begin as alloy steel billets



Curtiss-Wright 15' 1" diameter, CT6345-E Turbolectric Propeller on the Lockheed "Hercules", Model C-130A, Airplane.

STEEL

and Steel Products

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Please send more information on these Republic products:

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Name__________ Title__________

Company__________

Address__________

City__________ Zone____ State__________

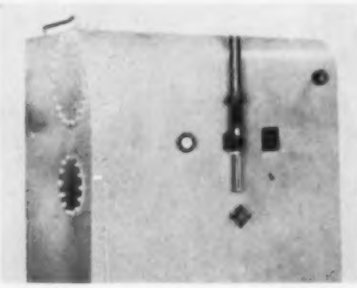
"PARK KASE GIVES US TOP QUALITY

Evans Reamer and Machine Company uses Park Kase Energizer #2 to case-harden track bushings up to 0.110" case depth. Inspecting track bushings that have been case hardened are (l. to r.): *from Evans: Lynn M. Leslie, Production Manager; LeRoy L. Johnson, Superintendent; William J. Blazek, President; from Park Chemical's Cincinnati Office, James F. Hetz.*

Engineering Digest of New Products . . .

Exothermic Gas Generator

A new exothermic generator which operates with any of the common gases has been announced by Sargeant & Wilbur, Inc. It produces atmospheres ranging from 10% O_2 to 11% CO without catalyst change. It is

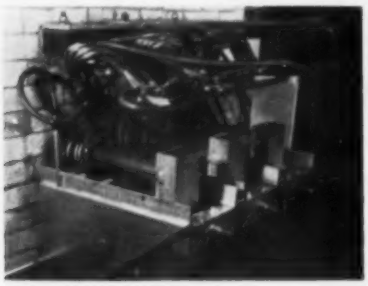


available in capacities up to 10,000 c.f.h. A newly designed cooling system has increased efficiency and has reduced replacement. Automatic mixing, easy starting, complete flow range and stable analysis are other advantages claimed.

For further information circle No. 283 on literature request card, page 32-B

Graphite Electrodes

A new continuing graphite electrode has been announced by Upton Electric Furnace Co. It can be continually fed, either manually or with motorized operation, through the salt



bath furnace wall as wear occurs. Some advantages claimed are a small electrode surface with lower secondary currents, inexpensive electrode replacement, metallic rectification eliminated, increased furnace life and reduced need of critical and costly electrode alloys. Graphite electrodes are available for temperatures to 3000° F. The accompanying illustration is of a pusher mechanism.

For further information circle No. 284 on literature request card, page 32-B

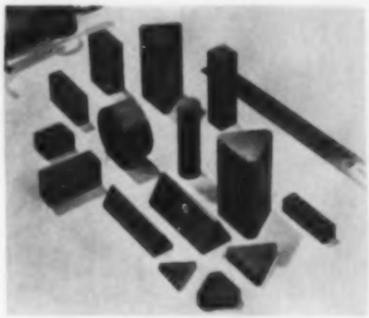
Thickness Gage

James G. Biddle Co. has announced a new gage for measuring the thickness of nonmagnetic coatings such as paints or plating on ferrous bases. It will determine thickness on radii, is not affected by vibration and temperature, will not damage coatings and is easy to use and carry. Its range is 0.0002 to 0.015 in. The Tinsley gage consists of a special light magnet attached to a spring and contained within a pencil-size tube. To make a measurement, the exploring head or magnet is placed on the surface and the body of the gage is drawn away, thus extending the spring. The spring extension is proportional to the force required to detach the magnet from the surface. The reading is taken at the point when the magnet breaks away from the surface, and from a calibration curve the coating thickness is determined.

For further information circle No. 285 on literature request card, page 32-B

Ceramic Cutting Tools

A new type of oxide-base cutting tool material has been announced by the Stupakoff Div. of the Carborundum Co. It will cut cast steel, cast iron, chilled iron, carbon steel and nonferrous materials. Tests have been made with speeds up to 2000 surface feet per minute. Machines that have ample rigidity and motor horsepower to employ tungsten carbide tools to the limit of their cutting ability have proved inadequate in getting full production capacity of Stupalox. It is said to cut with no build-up on the cutting edge and no cratering adjacent

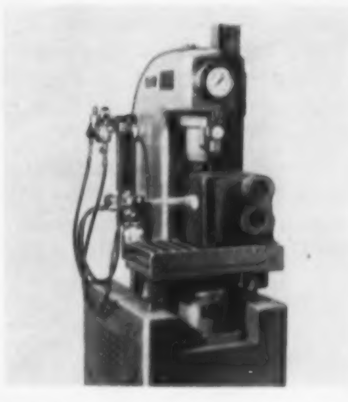


to it. It is reported harder than any metallic tool, more abrasion-resistant and maintains strength at temperatures detrimental to other materials.

For further information circle No. 286 on literature request card, page 32-B

Hardness Tester

Steel City Testing Machines, Inc., has announced a new Brinell hardness tester with a paint spray attachment. The attachment synchronizes with the testing cycle of the machine so that relative hardness of parts is automatically indicated by a spot of paint. The tester is designed to fit into a



roller conveyor. Brinell limits on the machine are adjustable in accordance with the user's requirements.

For further information circle No. 287 on literature request card, page 32-B

Coating

Chemical Corp. has announced a new chromate conversion coating for cadmium that will produce a bright clear

finish with corrosion protection. By using this material, a chromate leaching cycle requires two tanks less than is usual.

For further information circle No. 288 on literature request card, page 32-B

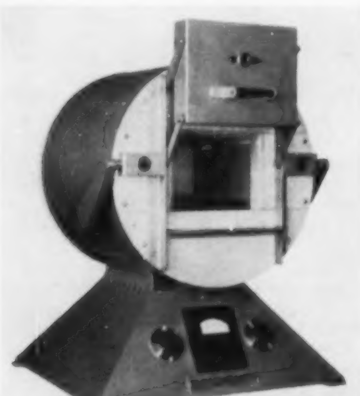
Selector Switch

Thermo Electric Co., Inc., has announced a series of rotary selector switches for either thermocouple or resistance bulb circuits and for flush panel or wall mounting. They are shorting-type, double-pole switches, with easily accessible contacts and wipers of the same silver alloy, so that the possibility of false voltages from thermo electric action is reduced. Copper wiring and bunched leads for soldered connection are standard; thermocouple material wiring and binding posts are optional. Three models are stocked: off to 6 point, off to 12 point and off to 24 point. Overall dimensions are 5½ by 6½ by 4⅝ in.

For further information circle No. 289 on literature request card, page 32-B

Furnaces

A new automatic muffle furnace for continuous operation to 1850° F. has been announced by Hevi Duty Electric Co. It is a self-contained unit with temperature indicating and control devices located in the pyramid-type furnace base. Power input is controlled by a 36 step tap-changing transformer. The heating chamber is 11 by 14 by 8 in. and is formed by four heating units which can be arranged to expose the element or reversed to form a muffled chamber.



For further information circle No. 290 on literature request card, page 32-B

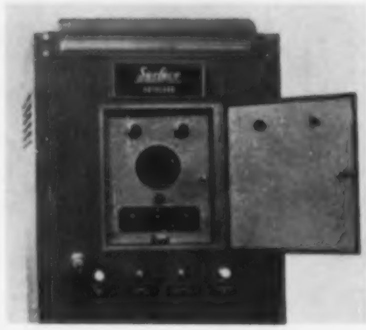
Ultrasonic Cleaning

Hermetically sealed ultrasonic power transducers and generators operating at 40 k.c. per sec. have been announced by Branson Ultrasonic Co. The large radiating surface of the transducers makes them suitable for ultrasonic metal cleaning applications as well as quenching, plating, pickling, descaling and dyeing. The standard transducer has a radiating area of 2⅝ by 6 in. The modular design facilitates a wide choice of arrangements, including flush transducer banks, focussing and diverging. They may be installed on conveyorized machines.

For further information circle No. 291 on literature request card, page 32-B

Dew Point Controller

A new automatic dew point controller for atmosphere generator or heat treat furnace has been announced by Surface Combustion Corp. It is applicable to processes such as gas carburizing, clean hardening and annealing, where a permanent record is not required. It is a completely self-contained unit and operates with an electronic control system using a resistance bulb as sensing element; signal lights provide high and low indication.



For further information circle No. 292 on literature request card, page 32-B

Fatigue Testing

Automatically maintained constant preload equipment on Sonntag simulated service fatigue machines of 400 lb. load capacity has been announced by Baldwin-Lima-Hamilton Corp. The new equipment corrects for creep which may be produced in test specimens such as machine parts or structural components while they are being subjected to constant fatigue loads in tension, compression, bending,

...its great strength
...its ease of fabrication

'ROUND AND 'ROUND the flywheel goes, at a speed of 300 mph. Suddenly, an aircraft wheel assembly rams against it, with the impact of a loaded airplane. The tire squeals, the brake is applied, and in just 20 seconds the wheel stops. A real rugged test—both for the wheel assembly and for the steel in the flywheel. USS "T-1" Steel passed the test. In fact it is the best steel that could be used for this high speed application.

High speed tire, brake, and wheel testing machines like the one shown here, manufactured by Adamson United Company, Akron, Ohio, a subsidiary of United Engineering and Foundry Co., are used to prove out aircraft landing gear. The gigantic flywheels on these machines simulate the speed and inertia of an actual airplane during landing and take-off.

Until a short time ago, testing machines were built to rotate at peripheral speeds up to 250 mph. But when the aircraft industry spread its wings, faster testing machines were needed. The new machines had to rotate at speeds as high as 300 mph—and stay in one piece. They had to be extremely strong . . . lightweight . . . and easy to fabricate.

That's when USS "T-1" Steel entered the picture.

For flywheels rotating 300 mph, a steel of extremely high tensile strength was needed to withstand the tremendous stresses generated. A steel permitting the greatest strength for the thinnest section was needed. And, above all, the steel had to be capable of developing full 100% weld strength.

USS "T-1" Steel more than met all Adamson United's requirements.

Other steels could have provided the strength and met the weight requirements. None but "T-1" provided these and good weldability too.

UNIQUE PROPERTIES—"T-1" Steel's unique combination of physical properties has solved many similar problems. "T-1" can be welded satisfactorily *without* pre- or post-heating—it can be welded either in the shop or field. Always, it provides great tensile strength (105,000 psi minimum with yield strength of 90,000 psi minimum), phenomenal toughness and excellent abrasion resistance. Write for full particulars. United States Steel, Room 5089, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

SEE The United States Steel Hour. It's a full-hour TV program presented every other week by United States Steel. Consult your local newspaper for time and station.

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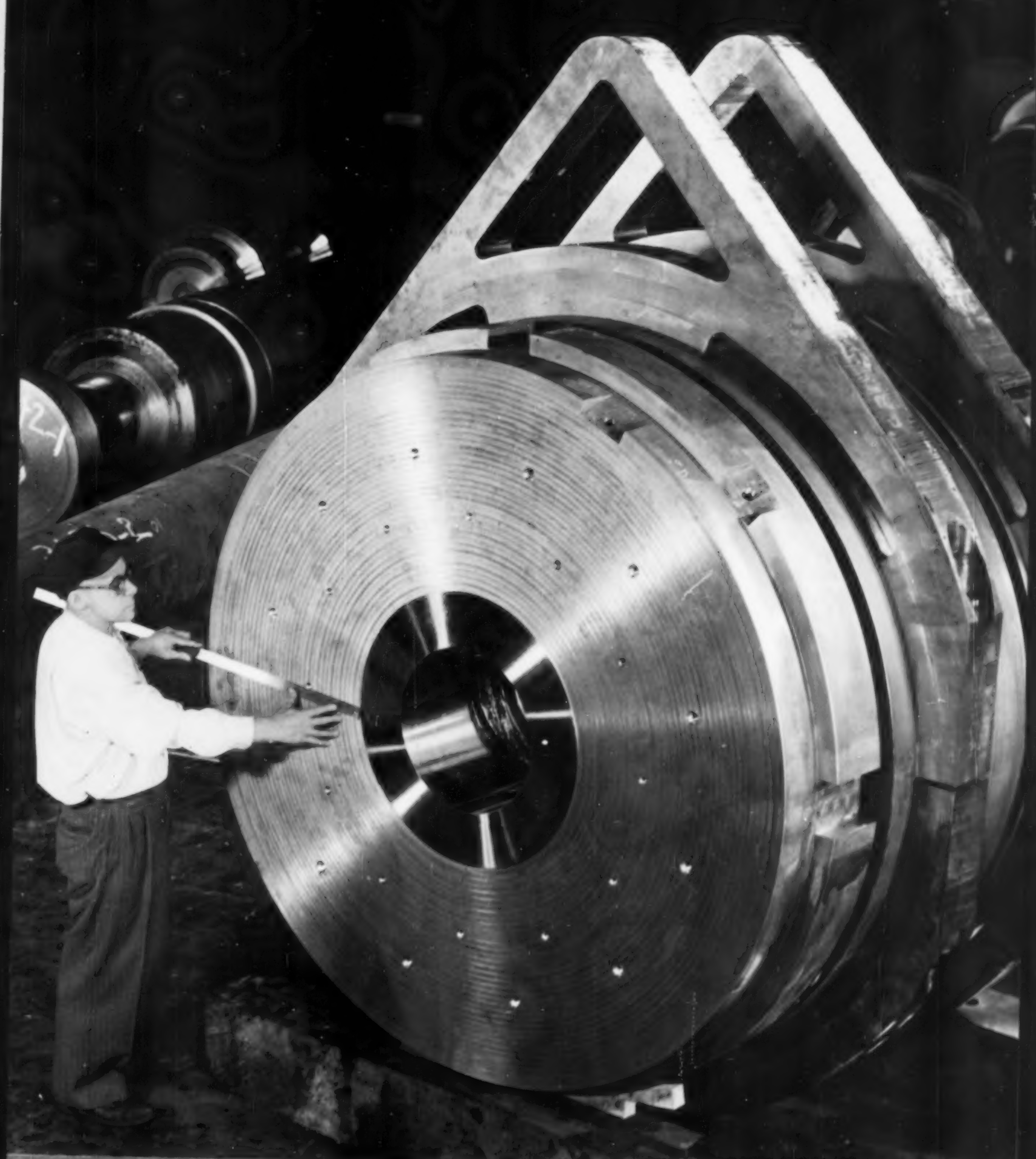
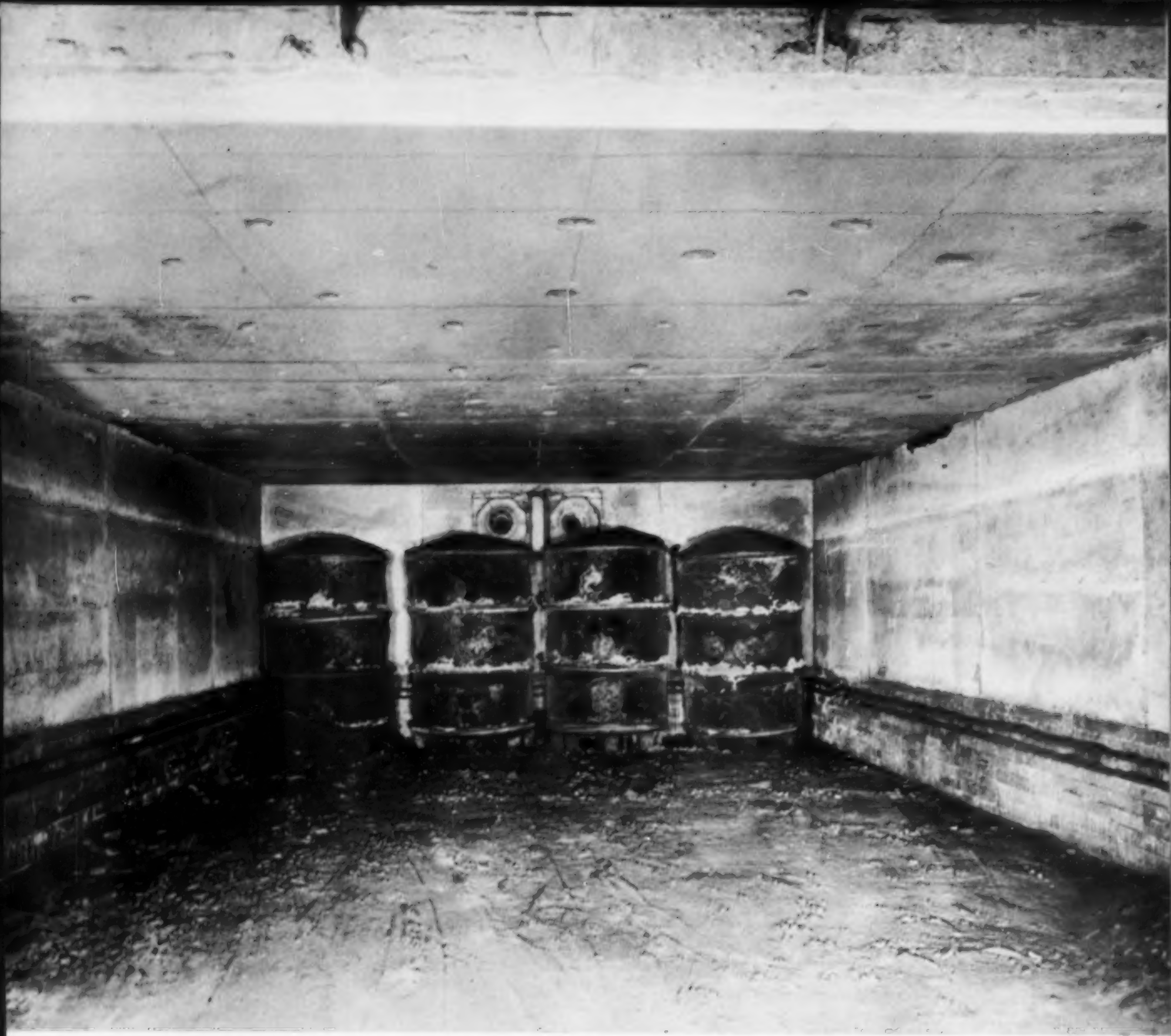
USS "T-1" CONSTRUCTIONAL ALLOY STEEL

UNITED STATES STEEL





SIDE WALLS AND FLAT ARCH ROOF on this batch-type annealing oven at Terre Haute Malleable & Mfg. Corporation, Terre Haute, Indiana, were installed quickly and economically with a castable refractory—Kast-O-Lite—a Lumnite-base castable manufactured by A. P. Green Fire Brick Company, Mexico, Mo.

CASTABLES: fast—economical—reliable

Lumnite-base castables are bringing new speed and economy to countless refractory installation and repair jobs. They're so easy to use. Just add water, mix, and you're ready to place refractory or insulating concrete.

Packaged castable mixes made with Lumnite* calcium-aluminate cement and selected aggregates are carefully proportioned to provide specific concretes to meet a wide range of temperature and insulation requirements. Because they are pre-mixed, such castables give quality results with added convenience. They are made and distributed by leading manufacturers of refractories.

Industrial concretes made with Lumnite cement or Lumnite-base castables have many uses—in forge plants and heat-treating shops, for annealing furnace car tops and roof arches, door linings, forge furnace arches; for furnace foundations, core ovens and many other installations. Write for detailed information.

UNIVERSAL ATLAS CEMENT COMPANY

UNITED STATES STEEL CORPORATION SUBSIDIARY

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* "LUMNITE" is the registered trade-mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.

MP-L-116

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When you run head-on into a die block or forging problem because of new materials, methods, or products, call a Finkl Sales Engineer. He has a wealth of very valuable information plus the advantage of 76 years of Finkl experience. It is yours for the asking.

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If you are concerned with:

Reactor development...
Atomic energy projects...
Nuclear problems...

This new data book will help you

This new free Norton *"Handbook on Boron Carbide and Elemental Boron"*, is a valuable reference, containing both fundamental data and practical information. Printed in colors with many charts and tables it will serve as a useful and permanent addition to the reference files of those concerned with atomic energy and related fields.

In nuclear science and engineering the importance of the neutron absorption reaction of the boron isotope B^{10} is well recognized.

Now, for the first time, available data on the development of numerous stable, boron-rich materials have been compiled and coordinated by Norton in one convenient reference book.

This book is the *"Handbook on Boron Carbide and Elemental Boron"* — a compact source of technical information on materials made by Norton for use in the atomic energy field.

A partial list of the table of contents includes: *Boron for neutron absorption . . . Technical grade boron . . . Properties of boron . . . Commercial grades of boron carbide . . . Radiation damage to boron carbide . . . Bonded boron carbide (carbon, silicate, plastic, metal) . . . Boron nitride . . . Metal borides.* These and many other subjects are fully described and illustrated with tables, charts and photographs.

A Quarter-Century of Experience

Work in Norton laboratories on boron compounds began some 25 years ago. This included the development of NORBIDE* boron carbide, the hardest material yet produced commercially. Norton facilities for producing NORBIDE wear-resistant articles and abrasive have been expanded to supply boron carbide in numerous forms for atomic energy applications.

Recent Norton development has been aimed at improving the quality, increasing the production and reducing the costs of various boron-rich products. As a result, Norton now produces these materials to highest purity standards, at prices ranging between one-half and one-tenth of former pricing.

Other Norton Electric Furnace Products

of special interest to nuclear engineers include ALUNDUM* fused alumina, CRYSTOLON* silicon carbide, MAGNORITE* magnesium oxide, FUSED ZIRCONIA and various refractory carbides, oxides and nitrides.

Besides being the basic ingredients of the famous Norton Refractory R's — refractories *engineered and prescribed* for the widest range of conventional applications — these high-melting materials are finding many new and valuable uses in atomic energy projects.

They are all described in the new Norton handbook. For your free copy, write to NORTON COMPANY, Refractories Division. 321 New Bond St., Worcester 6, Massachusetts.

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REFRACTORIES
Engineered... R ...Prescribed
Making better products... to make your products better

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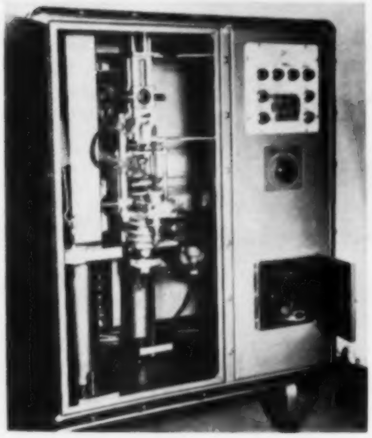
torsion, or combined stresses. Fatigue loads are produced in these machines by the centrifugal force of an eccentric mass rotating at 1800 rpm. Deflections vary with the condition of the



material under test. With maximum preload of 200 lb. the maximum movement of the vertically reciprocating load platen is 0.625±0.312 inch. Maximum movement without preload is 1±0.5 in.

For further information circle No. 293 on literature request card, page 32-B

Tumbling Barrel Rack

A new universal tumbling fixture which can be ordered to fit most sizes of horizontal barrels has been announced by Lord Chemical Co. It is built for assembly within the barrel. The outside framework, of heavy-gage machined steel, is adjustable to insure a right fit inside the barrel. The inner portion is a revolving ferris wheel with several work stations. Each station will accommodate one large part or several smaller parts. Rods or chains to hold parts are provided with rubber hose to prevent damage to the work parts.

For further information circle No. 294 on literature request card, page 32-B

Pyrometers

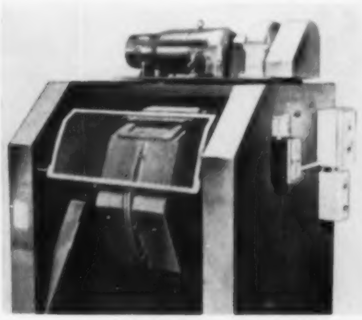
Servo Corp. has announced an infrared radiation instrument which measures temperature variations in situations where thermocouples, thermopiles, and other devices are in-

adequate or inoperative. The pyrometer covers a temperature range of room temperature to 1000° C. It indicates temperature variations as small as 0.1° F. Its response time is 0.025 sec.

For further information circle No. 295 on literature request card, page 32-B

Cutting Barrels

The Hartford Steel Ball Co. has announced two new triple action cutting barrels with 10 and 4 cu. ft. capacities.



Parts can be processed by any tumbling method—abrasive chip, ball and steel shape, branded compound or other medium for special jobs. The power unit is on top. Controls are grouped together and consist of drum-type reversing switch 24 hr. program timer, magnetic starter and brake and four-speed gear shift control, permitting rpm. speeds of 8, 11, 18 and 33 on the 10 cu. ft. model and slightly higher speeds on the 4 cu. ft. model.

For further information circle No. 296 on literature request card, page 32-B

Thermometers

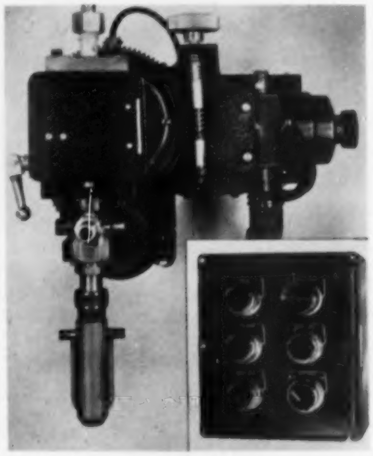
Vapor-pressure actuated thermometer systems which record on uniform charts, instead of the expanded charts previously necessary, have been announced by the Bristol Co. A patented varying-ratio linkage converts the nonlinear vapor pressure-tem-

perature curve into a linear deflection of the recording pen. The linkage is available for all ranges from —20 to 600° F. For cross ambient ranges, a dual-filled system with uniform scale is used to replace more expensive fully compensated Class 1 thermometers. Dual filled, linear systems are used for ranges under 200° F.

For further information circle No. 297 on literature request card, page 32-B

Automatic Welding

A new automatic welding head with a single motor drive has been announced by Air Reduction Sales Co. This unit is designed for automatic welding by the inert gas consumable electrode method. Argon, carbon dioxide and helium shielding gases and steel, aluminum, bronze and stainless welding wires from 0.030 in. in diameter can be used. The new head has a continuous current rating of 600 amp. Controls are simplified.



For further information circle No. 298 on literature request card, page 32-B

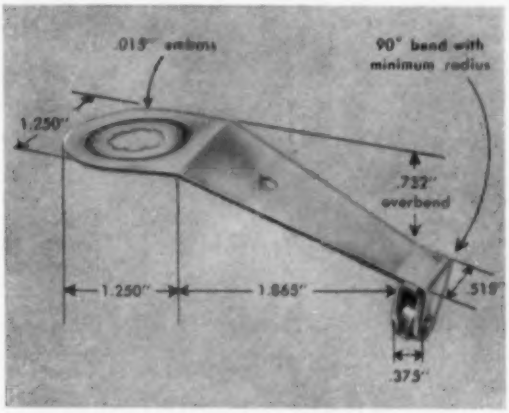
Enameling Furnace

The Waltz Furnace Co. has announced a continuous enameling electric furnace. This 225 kw. furnace has an overall length of 30 ft. which includes a 6-ft. preheat chamber, 18-ft. heating chamber and 6-ft. cooling chamber. It is equipped with continuous overhead conveyor.

For further information circle No. 299 on literature request card, page 32-B

This railroad runs better, will last longer

A Type ZW Lionel Trainmaster Control has four independent variable voltage circuits, can operate four trains simultaneously.



One of the four variable voltage taps in a Type ZW Lionel Trainmaster Control, now made of .0150" thick Duraflex in spring temper. This temper in Duraflex provides the extra strength needed—with the same forming properties as conventional phosphor bronze in extra hard temper.

Lionel switched to DURAFLEX *for the hardest working parts of its Trainmaster controls*

Much of the fun of model railroading depends on the smooth, dependable performance of its controls. That's why Lionel makes its Trainmaster controls tough, precision instruments – constantly guards their quality.

Lionel had been using an ordinary phosphor bronze in the vital, hard-working variable voltage taps. But they were troubled with fractures in forming the bends. To maintain their quality standards, they considered using another alloy, at substantially increased cost.

First, however, they tried Duraflex*, Anaconda's new superfine-grain phosphor bronze. The fractures were eliminated. The press room found the forming qualities of Duraflex excellent. The Transformer Department was pleased with the reduction in rejects, found the strength and resilience better.

So Lionel has controls of superior quality – at no extra cost – for Duraflex costs no more than ordinary phosphor bronze.

Duraflex, because of its superfine-grain structure, offers greatly improved fatigue resistance and formability. It also has a finer, smoother, harder surface, plus good electrical conducting properties and high corrosion resistance. It is produced in sheet metal up to 0.062" thick and in wire up to 3/16" diameter. We will provide free samples for test purposes – specify gage and temper. Write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

*Trade Mark

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with 30% Greater Endurance Limit

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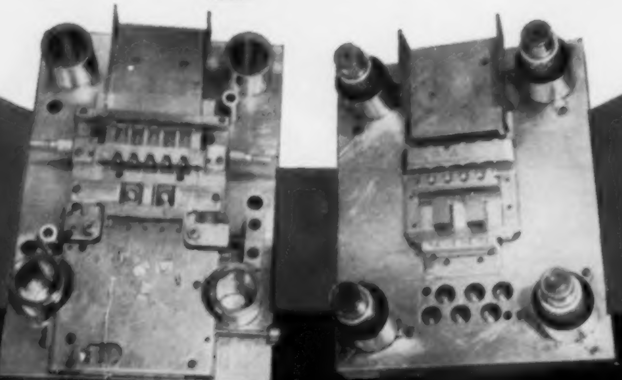
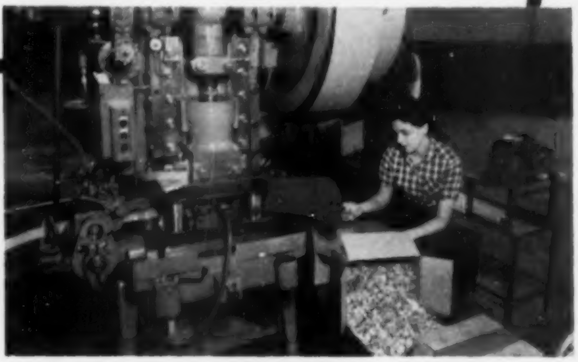


produced 68,000,000 parts

. . . and ready for more!

Fisher Industries, Inc., Birmingham, Mich. used DESEGATIZED® Olympic FM die steel because . . .



1 Excellent wear resistance of Olympic FM extended the normal life of the die.

2 An estimated 25-30% savings in machining costs has been experienced with Olympic FM dies of this type.

At Fisher Industries, Inc., Birmingham, Mich., the Olympic FM die (shown above) blanks and forms universal clips from .031″-.037″ zinc plated #4 Temper 1010 cold rolled steel. When photographs were taken, a total of 68,000,000 pieces had been produced on a press operating at 330 strokes per minute fabricating 5 clips per stroke.

Die makers and users throughout the metal-working industry have found that Latrobe's Olympic FM die steel consistently results in lower die production costs, superior machined finishes, and longer production runs than comparable type die steels. One of Latrobe's DESEGATIZED● steels, Olympic FM is a free-machining high carbon-high chromium die steel . . . the improved machinability characteristics resulting from the addition of alloy sulphides uniformly dispersed by the DESEGATIZED● process of manufacture.

For improved machinability and long production runs, order Olympic FM . . . Over 250 sizes are stocked in ten conveniently located warehouses.

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Main Office and Plant
LATROBE, PENNSYLVANIA

Branch Offices and Warehouses in Principal Cities

What's New In Manufacturers Literature . . .

301. Allowable Stresses
Data Card 154 gives max. allowable stress values for 22 types of steel tubing. Formulas for calculation of max. working pressures. *Babcock & Wilcox*

302. Alloy Castings
8-page bulletin on alloy castings for heat treating. *Ohio Steel Foundry*

303. Alloy Castings
Data folders on two types of alloy steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

304. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

305. Alloy Steel
40-page book on applications of heat treated. special alloy steel. *Jones & Laughlin*

306. Alloy Steel
32-page book on abrasion resisting steel. Properties, fabricating characteristics, uses. *U. S. Steel*

307. Alloy Tools
44-page book on cast Stellite tools for metal cutting. *Haynes Stellite*

308. Aluminum Alloy
Folder on plates and bars of copper-silicon-aluminum alloy. Case histories. *Pioneer Tool Engineer*

309. Aluminum Alloys
New booklet on how to melt and cast aluminum alloys. *Geo. Sall Metals*

310. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

311. Aluminum Extrusions
28-page book on extruded aluminum products. Design, tolerances, applications. *Revere*

312. Aluminum Heat Treating
8-page Bulletin 5912 on solution heat treating, annealing, stabilizing and aging of aluminum. *General Electric*

313. Ammonia Atmospheres
12-page bulletin B-52 on dissociated ammonia furnace atmospheres. *Drever*

314. Annealing Copper
Reprint 55-D on how to anneal copper tubing. Furnaces, contamination control, brightening. *Surface Combustion*

315. Annealing Furnaces
8-page illustrated booklet on continuous annealing furnaces. Schematic diagrams, photographs, and actual production data. *Drever*

316. Atmosphere Cooling
Bulletin T-40 on automatic heat treating units with controlled atmosphere cooling. *Ipsen Industries*

317. Atmosphere Furnace
12-page bulletin on controlled atmosphere reciprocating hearth furnace for continuous hardening, light case carburizing, Ni-Carb ammonia-gas carburizing and other heat treating processes. *American Gas Furnace*

318. Atmosphere Furnace
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

319. Atmosphere Furnace
12-page bulletin on electric furnaces with atmosphere control for hardening high speed steel. *Sentry*

320. Atmospheres
12-page booklet on design and use of special atmospheres for industrial furnaces. *Continental Industrial Engineers*

321. Atmospheres
New 12-page bulletin on use of protective atmospheres to prevent deterioration of metals during various heat treating processes. *General Electric*

322. Atmospheres
Bulletin 1-10 supplies technical information on inert gas generators and data on costs. *C. M. Kemp Mfg.*

323. Atmospheres
Bulletin 439 on exothermic atmosphere generators for converting natural gas, manufactured gas, propane or butane. *W. S. Rockwell*

324. Automation
Two articles on automation for modern heat treating in Heat Treat Review, Vol. 7, No. 2. *Surface Combustion*

325. Barrel Finishing
32-page handbook on compounds for descaling, deburring, coloring, metal cleaning and rust inhibition. *Lord Chem.*

326. Beryllium Copper
Bulletin 1 on available alloys, conditions, tempers and tables of sizes and properties. *Penn Precision Products*

327. Beryllium Copper
New 12-page bulletin 6 offers suggestions for ordering beryllium copper strip. Available alloys, tempers, sizes and tolerances. *Penn Precision Products*

328. Bimetal Applications
36-page booklet, "Successful Applications of Thermostatic Bimetal", describes 22 uses. *W. M. Chace*

329. Brass
New 20-page pocket-size booklet on brass rod mill products. Weight tables, specifications and other technical data. *Titan Metal Mfg. Co.*

330. Brazing
Bulletin 5889 on furnace and induction brazing installations and methods. *General Electric*

331. Brazing Alloys
File includes physical property data on commercial silver solder and cross index of commercial designations and ASTM and government specifications. *Goldsmith Bros.*

332. Buffing Compounds
Bulletin B-7 lists various compounds and gives applications. *Apothecaries Hall*

333. Burners
8-page reprint No. 43 on Method for Improving Temperature Uniformity in Furnaces. *North American Mfg.*

334. Carbides
4-page bulletin describes tungsten carbide grades for cutting nonferrous metals and cast iron, for cutting steel, for die applications and special purpose grades. *Adamas Carbide Corp.*

300. Tube Mills
Electric-weld tube making, its development and scope, both economical and mechanical, is discussed in this 64-page booklet. Costs involved, labor, maintenance, scrap loss and other factors in selecting tube mills comprise the first half of the booklet which also contains a

section on various tube making processes with special emphasis on the electric-weld method. Physical characteristics which must result from the process to meet requirements for chromium plating, bending and fabricating are included. The last part of the bulletin gives engineering data and specifications. *Yoder Co.*

335. Carbides
84-page catalog of sintered carbides, hot pressed carbides, cutting tools, drawing dies, wear resistant parts. *Metal Carbides*

336. Carbon Control
Bulletin C-22 and reprint on Carbotronik for automatic control of carbon potential of atmospheres. *Ipsen*

337. Carburizing
Data folder on Aerocarb E and W water-soluble compounds for liquid carburizing. Case depth vs time curves. Per cent carbon and nitrogen penetration curves. *American Cyanamid*

338. Casehardening
32-page booklet on casehardening of steel by nitriding. *Armour Ammonia Div.*

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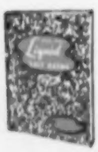

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339. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

340. Chromium Stainless
12-page book on fabrication and use of Type 430 stainless steel. *Sharon Steel*

341. Chromium Treatment
Reprint describes how chromium impregnating of steel affects properties, how it is done, applications. *Chromalloy*

342. Cleaner
Folder gives data on metal cleaners for use with water in still-tank or spray-washing equipment. *Solventol*

343. Cleaning
New 8-page booklet on wetting agents, detergents, emulsifiers. *E. F. Houghton*

344. Cleaning
44-page booklet, "Some Good Things to Know About Metal Cleaning", discusses tank, barrel and machine cleaning, pickling, zinc phosphate coating, rust prevention and other processes. *Oakite*

345. Coatings
Folder on Kelite 25, paint bonding coating. *Kelite*

346. Coatings
New Bulletin 7-2 on neoprene heavy duty, extra heavy duty, styrene, chlorinated rubber and epoxy resin based coatings. *Atlas Mineral Products Co.*

347. Cobalt Alloy
12-page booklet, "Haynes Alloy No. 25", tells of the unique properties of this cobalt-base alloy. *Haynes Stellite*

348. Cold Finished Bars
Engineering bulletin, "New Economies in the Use of Steel Bars". *LaSalle Steel*

349. Cold Rolled Steels
32-page booklet on stainless, alloy and carbon spring steels, and other specialties. Melting, temper, finishes. *Crucible Steel*

350. Compressors
12-page data book 107-D gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

351. Controlled Atmospheres
Bulletin 753 on generator for atmospheres for hardening, brazing, sintering and annealing carbon steels. *Hevi Duty*

352. Controller
12-page bulletin 5A-13 on pneumatic indicating controller for control of process variables. *Foxboro*

353. Controllers
80-page catalog 8305 on nonindicating electric, electronic and pneumatic controllers for temperature, pressure and humidity. *Minneapolis-Honeywell*

354. Copper Alloys
40-page book on eleven copper alloys. Properties, cleaning, annealing. *Seymour*

355. Corrosion Resistance
20-page bulletin on copper alloys for corrosion resistance. Table gives applicability in 150 media. *Ampco*

356. Corrosion Resistant Alloy
20-page booklet on nickel, chromium, molybdenum, iron alloy gives chemical composition, corrosion data, properties and welding characteristics. *Haynes Stellite*

357. Creep Testing
Bulletin 4208 on five types of creep testing machines for standard sized metal specimens. *Baldwin-Lima-Hamilton*

358. Creep Testing
Bulletin RR-13-54 on new creep testing machine. *Riehle*

359. Cut-Off Wheels
Folder gives data, operating suggestions and grade recommendations of cut-off wheels. *Manhattan Rubber Div.*

360. Cutting Oil
Facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids" booklet. *Cities Service*

361. Cutting Tools
36-page booklet analyzes and compares carbon, high speed, cast alloy and carbide tool materials. *Allegheny Ludlum*

362. Degreaser
40-page book on properties and use of trichlorethylene. Methods of handling and safety measures. *Niagara Alkali*

363. Degreasing
34-page booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

364. Descaling
Bulletin on new machines for descaling steel sheets, plates and coils after hot rolling or heat treating. *Pangborn Corp.*

365. Descaling
24-page book "Handling Metallic Sodium" with special reference to sodium hydride descaling. *U. S. Ind. Chem.*

366. Diamond Abrasive
4-page folder on the advantages of diamond abrasives for polishing metallurgical specimens. *Buehler, Ltd.*

367. Die Casting
Folder on molds for plastics and die casting dies. Case histories. *Parker Stamp Works*

368. Dryers
New 52-page Bulletin D-100 on dryers for air, gas and liquids for low dew points. *C. M. Kemp Mfg. Co.*

369. Ductile Iron
New 28-page bulletin gives advantages and applications of ductile iron. Properties. *International Nickel Co.*

370. Dust Control
24-page bulletin 98 on dust control describes and diagrams systems and their operation, gives capacities of filters and kinds of dust which may be controlled. *W. W. Sly Mfg. Co.*

371. Dynamometers
4-page folder on precision dynamometers for measuring traction, tension or weight. Capacities from 0 to 500 lb. to 0 to 100,000 lb. *W. C. Dillon*

372. Electric Furnaces
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

373. Electric Furnaces
Bulletin on electric heat treating furnaces gives summary of progress in furnace developments. *Holcroft*

374. Electric Furnaces
Catalog of electric furnaces and ovens for hardening, tempering, annealing, drawing, drying, baking, enameling. *Cooley Electric Mfg.*

375. Electric Furnaces
Folder on electric furnaces with zone control, temperature indication, automatic control. *L & L Mfg. Co.*

376. Electron Microscope
20-page booklet on special features and uses of electron microscope. *RCA*

377. Environmental Cabinets
New bulletin on cabinets from 1 to 45 cu. ft. capacity, and from +300 to −200° F. ranges. *Webber Eng.*

378. Fabrication
Booklet on welded steel heavy fabrication pictures and describes how various products are made. *R. C. Mahon*

379. Filters
New catalog sheets on six types of filters—portable, mobile, stationary from 250 to 18,000 gal. per hr. capacity. *Bart-Messing*

380. Finishing Compounds
Set of 4-page brochures on compounds for heavy deburring and cutting, deburring and semi-burnishing, burnishing, cleaning. *Newton Industries*

381. Flow Meters
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g.*

382. Fluxes and Grain Refiners
Data sheets on potassium titanium fluoride, potassium zirconium fluoride, potassium fluoroborate give physical and chemical properties, analyses, uses. *Kawecki Chemical Co.*

383. Forgings
New bulletin on forge steel making, open die forging, machining, heat treating and finishing. *National Forge*

384. Forgings
94-page book on die blocks and heavy-duty forgings. 20 pages of tables. *A. Finkl & Sons*

385. Forgings
12-page booklet on how forged weldless rings and flanges are made. Case histories. *Standard Steel Works Div.*

386. Forgings
Series of articles on modern forging methods. *Hill Acme*

387. Forgings
Folder on large forgings of carbon and alloy steel. *Struthers Wells Corp., Titusville Forge Div.*

388. Formed Shapes
New 26-page catalog No. 1555 contains drawings and dimensions of more than 100 shapes. *Roll Formed Products Co.*

389. Forming Lubricants
Field report 18-55 on lubricant for forming, drawing, thread rolling, stamping, coining, punching. *Alpha Molykote*

390. Forming Dies
Bulletin No. 205 on aluminum powder reinforced epon resin casting compound for forming dies. *Metals Disintegrating*

391. Fuels
8-page booklet tells of the rapid growth and uses of liquefied petroleum gas. *Gulf Oil Corp.*

392. Furnace
Bulletin on new muffle furnace describes insulation, heating and instrumentation. *Hevi Duty Electric*

393. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

394. Furnace Belts
New 42-page booklet on alloy steel belts for continuous high-temperature furnaces. Belt selection guide. *Wickwire Spencer Steel Div.*

395. Furnaces
Bulletin on controlled atmosphere furnaces and generating assemblies for annealing, brazing, hardening, sintering, soldering. *Sargeant & Wilbur, Inc.*

396. Furnaces
New vacuum furnace bulletin. *National Research Corp.*

397. Furnaces
Folder on new sizes, specifications for soft metal reverberatory furnaces. *Eclipse Fuel Engineering*

398. Furnaces
Data on luminous wall forging furnaces. *A. F. Holden*

399. Furnaces
Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

400. Furnaces, Heat Treating
12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

401. Furnaces, Heat Treating
32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

402. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood Corp.*

403. Gas Cutting
New 20-page catalog on construction features of oxyacetylene multiple-torch, shape-cutting machines. *Air Reduction Sales*

404. Gold Plating
Folder on salts for bright gold plating. Equipment needed. *Sel-Rex*

405. Graphitic Tool Steels
48-page booklet on heat treating data, properties and 46 specific applications of graphitic tool steel. *Timken*

406. Grinding
30-page catalog of grinding wheels. Sizes, specifications, wheel speeds, standard types. *Peninsular Grinding Wheel*

407. Grinding
31-page booklet on abrasive belt grinding. Applications and advantages. *Engelberg Huller Co.*

408. Grinding Wheels
New 22-page booklet contains articles on how to select wheels for precision grinding of tool and constructional steels. *Norton Co.*

409. Hard Surfacing
Data sheets on 5 newly developed hard surfacing alloys. Characteristics, hardness, wear resistance. *Coast Metals*

410. Hardness Conversion
Chart comparing various testing systems and tensile strength of carbon and alloy steels. *Babcock & Wilcox Co.*

411. Hardness Conversion
Celluloid card, 2¾ x 4¾ in., gives approximate relationship between Brinell, DPH (Vickers), Rockwell and Shore Scleroscope hardness values and corresponding tensile strengths of steels. *International Nickel*

412. Hardness Tester
Bulletin on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman*

413. Hardness Tester
Bulletin on hardness tester for all regular and superficial Rockwell tests. *Kent Cliff Div., Torsion Balance Co.*

414. Hardness Tester
Literature on Brinell testing machines. *Detroit Testing Machine Co.*

415. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

416. Heat Exchanger Tube
Bulletin TB-329B on seamless or welded tubes of carbon, alloy and stainless steel for heat exchanger and condenser tubes. *Babcock & Wilcox*

417. Heat Processing
Bulletin answers questions: what is to be heated, what sections are to be heated, why the material is to be heated, to what temperature and for how long. *Selas*

418. Heat Treating
Loose leaf data sheets on heat treating oils, salts, carburizing compounds. *Park Chemical*

419. Heat Treating
20-page catalog on the Homocarb method with Microcarb atmosphere control for heat treatment of steel. *Leeds & Northrup*

420. Heat Treating Ammonia
24-page "Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div.*

421. Heat Treating Fixtures
32-page Catalog G-10 covers heat and corrosion resistant fabricated alloy products. Includes furnace muffles, trays, fixtures, retorts, pit-type furnace equipment, salt bath equipment, pickling and plating equipment. *Rolock, Inc.*

422. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

423. Heat Treating Fixtures
12-page bulletin on wire mesh baskets for heat treating and plating. *Wiretex*

424. Heat Treating Guide
Chart guide constructed on slide rule principle for simplified hardening and drawing of tool steels. *Carpenter Steel*

425. Heat Treating Pots
Bulletin 110 gives data on sizes and shapes of cast nickel-chromium solution pots. *Fahralloy*

426. Heat Treatment
Bulletin gives normalizing, annealing, quenching temperatures and Rockwell hardness for 44 standard steels. *Swift Industrial Chemical*

427. High-Alloy Castings
New 16-page bulletin, No. 3354-G, gives engineering data concerning castings used for resisting high temperatures, corrosion and abrasion. *Duraloy Co.*

428. High-Strength Bronze
12-page booklet on telnic bronze with high strength, high hardness, good machinability, age hardenability, corrosion resistance. *Chase Brass*

429. High-Strength Steel
26-page booklet on properties, uses, applications of high-tensile low-alloy steel. *Jones & Laughlin*

430. High-Strength Steel
66-page catalog on Mayari®R steel. Applications which take advantage of its wear and corrosion resistance. *Bethlehem Steel*

431. High-Temperature Alloy
Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys Div.*

432. High-Temperature Lubrication
Bulletin on colloidal graphite lubrication of kiln cars, oven conveyors and forging dies. *Acheson Colloids*

433. High-Temperature Steels
87-page book on factors affecting high-temperature properties. 45 pages of data on tensile, creep and rupture properties of 21 high-temperature steels. *U. S. Steel*

434. Immersion Heating
4-page bulletin H-11 on correct selection, sizing and installation of equipment for immersion heating. *Eclipse Fuel Eng.*

435. Induction Furnace
New 4-page folder on combination induction melting and holding furnace and automatic pouring unit. *Ajax Engineering*

436. Induction Heating
36-page bulletin on high-frequency induction heating unit for brazing, hardening, soldering, annealing, melting and bombarding. *Lepel*

437. Induction Heating
60-page catalog tells of reduced costs and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

438. Induction Melting
16-page booklet 14-B on high-frequency converter type furnaces for induction heating and melting of ferrous and nonferrous metals. *Ajax Electrothermic*

439. Inspection
Data on ultrasonic inspection with the Reflectoscope. *Sperry Products*

440. Instruments
8-page bulletin on panel and portable temperature instruments and their controls and dew point instrumentation. *Illinois Testing Labs.*

441. Instruments
New catalog No. 175 on temperature measurement instruments of the optical, micro-optical and radiation types. *Pyrometer Instrument Co.*

442. Insulation
40-page industrial products catalog on insulations, refractory products and others. *Johns-Manville*

443. Laboratory Furnaces
Bulletin No. 310 on high temperature electric tube furnaces. *Burrell*

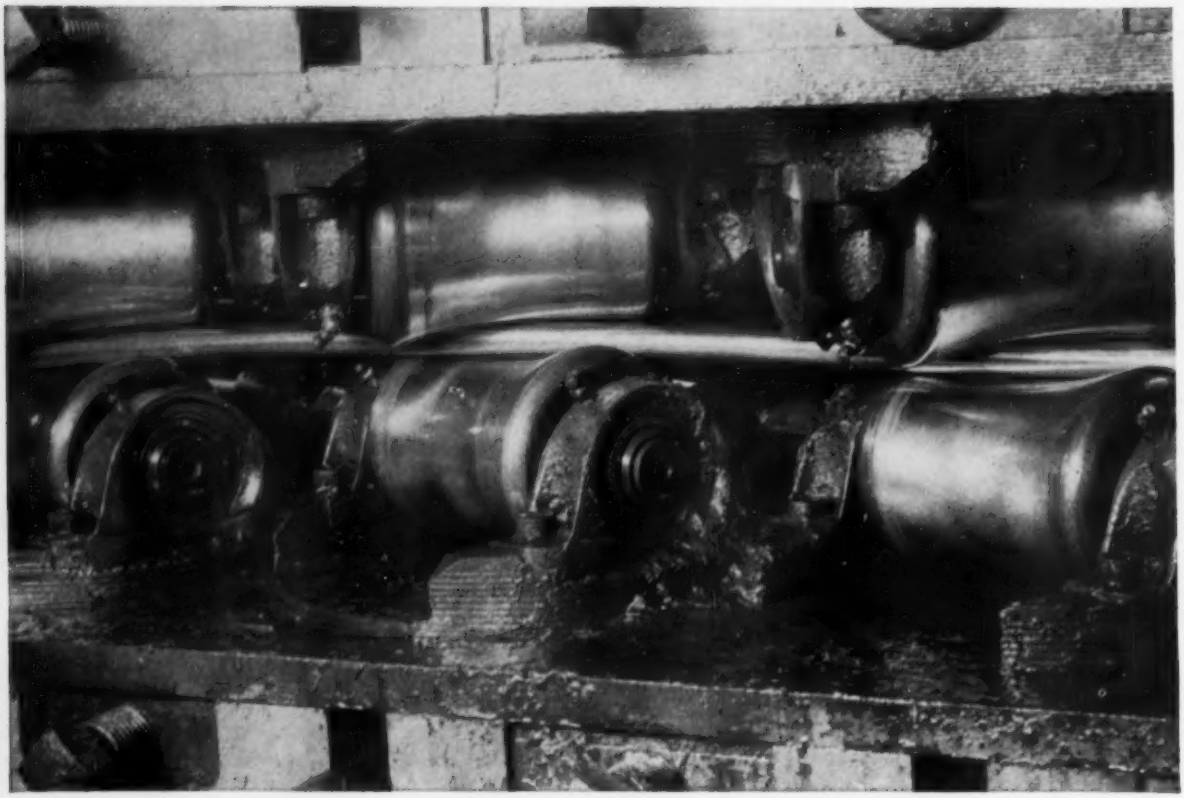
444. Laboratory Furnaces
Folder describes and illustrates tubular furnace for use in tensile testing, and control panels. *Marshall Products*

445. Leaded Steel
Folder on lead-bearing, cold finished bars which machine about 80% faster than B1113. *LaSalle Steel*

446. Leak Detector
16-page bulletin on leak detector for location and measurement of leaks in evacuated or pressure systems. *Consolidated Vacuum Corp.*

447. Low-Alloy Steel
16-page bulletin A-61 gives corrosion resistance, forming and working qualities, design factors. *International Nickel Co.*

448. Lubricant
8-page folder describes use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Corp.*



Uses tool steel that outwears others 3 to 1 for its straightener rolls

TO help its customers get the longest possible life out of the rolls used in its small tube straighteners, Mackintosh-Hemphill Division of E. W. Bliss Co. makes them from Graph-Mo® steel.

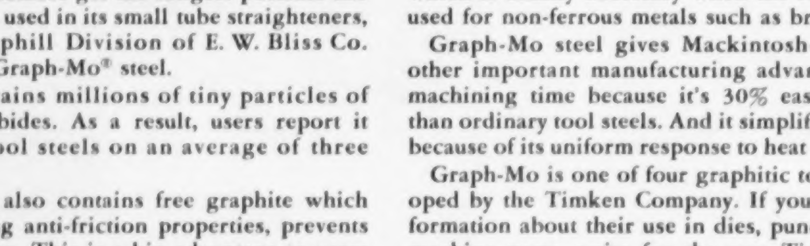
Graph-Mo contains millions of tiny particles of diamond-hard carbides. As a result, users report it outwears other tool steels on an average of three to one!

Graph-Mo steel also contains free graphite which gives it outstanding anti-friction properties, prevents pick up and scoring. This is a big advantage to users of small Mack-Hemp straighteners because it results in a better surface on the products being processed. What's more it eliminates chrome plating the rolls, which is usually necessary when the straighteners are used for non-ferrous metals such as brass.

Graph-Mo steel gives Mackintosh-Hemphill two other important manufacturing advantages. It saves machining time because it's 30% easier to machine than ordinary tool steels. And it simplifies heat treating because of its uniform response to heat treatment.

Graph-Mo is one of four graphitic tool steels developed by the Timken Company. If you want more information about their use in dies, punches, gages and machine parts, write for the new Timken Graphitic Steel Data Book. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH



SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS TUBING

449. Machining Titanium
Four discussions of methods, problems, chip formation in grinding and machining titanium. *Cincinnati Milling Machine*

450. Magnesium
42-page booklet on wrought forms of magnesium. Includes 31 tables. *White Metal Rolling & Stamping*

451. Magnesium-Zirconium
10-page reprint on an investigation of zirconium chloride, zirconium fluoride, 40% zirconium-magnesium material for making magnesium zirconium alloys. *Titanium Alloy Mfg. Div.*

452. Malleable Iron
Reprint 51-B on metallurgy, treatment and heat treated properties of malleable iron. *Surface Combustion*

453. Malleable Iron
12-page Bulletin 5797 on electric-furnace annealing of malleable iron. *General Electric*

454. Master Alloys
Data sheets on titanium-aluminum, titanium-boron-aluminum, boron-aluminum and zirconium-aluminum master alloys. *Kawecki Chemical Co.*

455. Melting Aluminum
Bulletin 310 on furnaces for melting aluminum. *Lindberg Eng'g*

456. Melting Furnaces
28-page catalog on Heroult electric melting furnaces. Types, sizes, capacities, ratings. *American Bridge*

457. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance Co.*

458. Microscopes
Catalog on metallograph and several models of microscopes. *United Scientific*

459. Mill Lubrication
Field report on high temperature, extreme bearing pressure lubricants for steel and nonferrous mills. *Alpha Molykote*

460. Moisture Measurement
12-page bulletin on how to measure water vapor in air and other gases. Gravometric, dew point and wet and dry bulb methods, and others. *Pittsburgh Lectrodryer*

461. Molybdenum
New folder on pallet method of shipping molybdenum. *Molybdenum Corp.*

462. Nickel Chromium Steels
8-page bulletin with 28 charts on composition, heat treatment, transformation characteristics and mechanical properties of the standard nickel-chromium steels. *International Nickel*

463. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

464. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

465. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

466. Ovens
Bulletin 10-S on cabinet ovens describes those for use with gas, electric and steam heat for temperatures to 600° F. *Young Brothers*

467. Ovens
16-page bulletin No. 53 on various types of core and mold ovens, special ovens and heat treating furnaces. *Carl-Mayer*

468. Periodic Chart
Periodic chart of the elements, green and black, 11 by 14 in., official 1952 data. *General Electric*

469. Pickling
80-page book, "Efficient Pickling", covers all variables of process. Many charts and tables. *American Chemical Paint*

470. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

471. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

472. Plating
Folder on electroplating with metal fluoborate solutions—lead, tin, iron, copper, nickel, cadmium and indium. *Baker & Adamson*

473. Plating
4-page folder on heat exchangers for plating, pickling and anodizing solutions. *Carl Buck & Assoc.*

474. Plating
Data sheet 5.1-4 on temperature control of plating tanks describes electric and pneumatic temperature control, recording, indicating and non-indicating instruments. *Minneapolis-Honeywell*

475. Plating Equipment
12-page bulletin on selenium rectifiers for electroplating and anodizing. *Hanson-Van Winkle-Munning*

476. Plating Equipment
New 12-page catalog 7115 on rubber lining for corrosion, abrasion, contamination resistance. *Raybestos-Manhattan*

477. Plating Solutions
Operating manuals for plating with metal fluoborate solutions. *Baker & Adamson.* See page 125.

478. Powder Metal
Powder properties, lubricants, sintering, coining and annealing, pressures and molding characteristics, alloy applications, physical properties of stainless metal powders. *Alloy Metal Powders*

479. Powder Metallurgy
New 18-page bulletin summarizes the process, designing for powder metallurgy, typical applications. *Keystone Carbon*

480. Powder Metals
Data on lubricant for oil impregnated sintered metals. *Alpha Molykote*

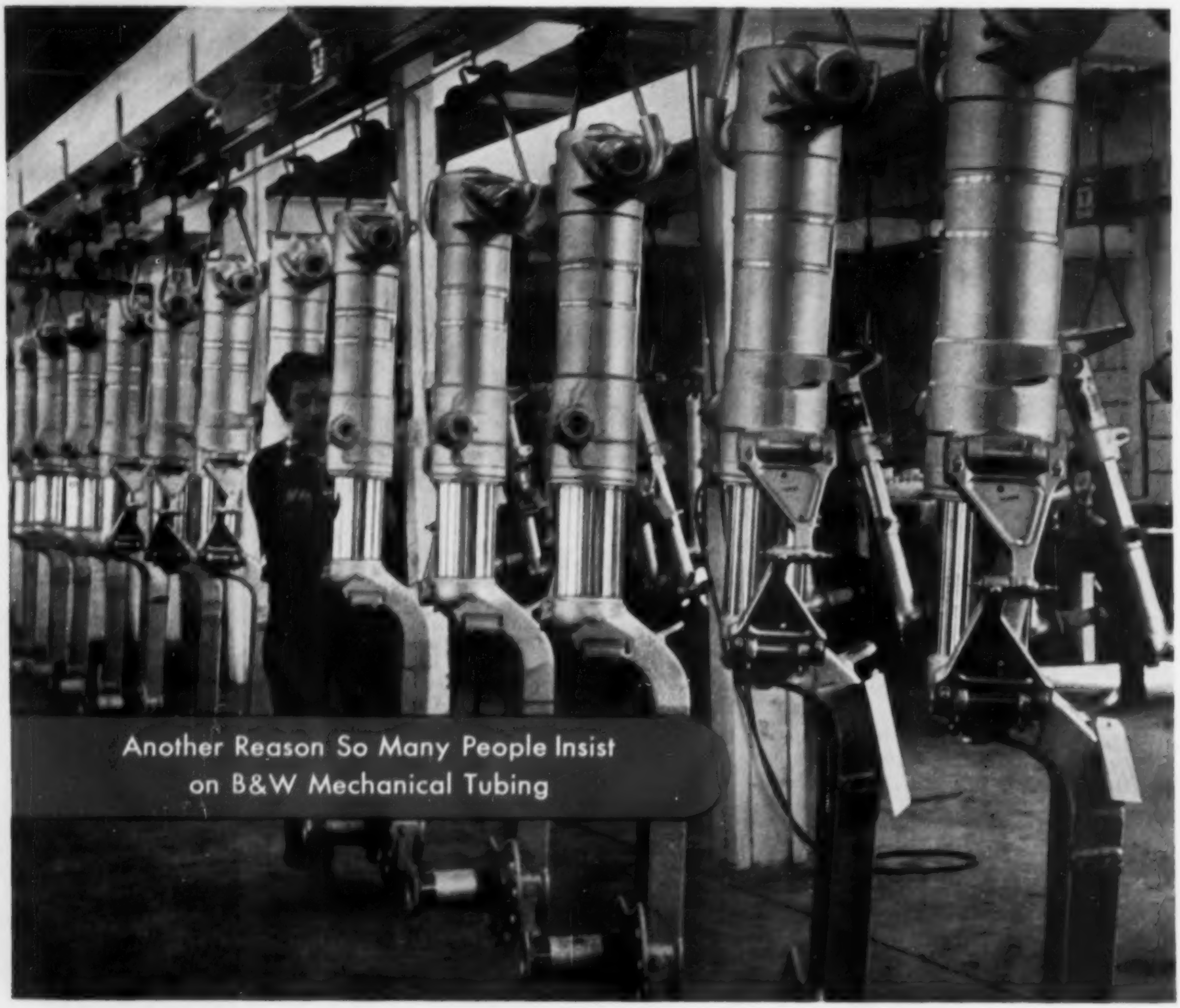
481. Powdered Metals
Booklet tells how things are made of powdered metals, applications and future possibilities. *Stokes*

482. Precision Casting
12-page book on alloy selection and design for precision casting. *Arwood Precision Casting*

483. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

484. Precision Casting
12-page book tells when to use precision castings, tolerances, how castings are made. *Alexander Saunders*

(Continued on page 32-A)



BUILDING THE LITTLE CLICK THAT SAYS ALL IS WELL

Every pilot who ever flew an airplane knows that the world's most reassuring sound is the little click that says "landing gear down *and locked.*" It's important because it means a safe landing. It insures coming in on your wheels instead of your belly.

Providing that reassurance is the job of Menasco Manufacturing Company, which specializes in the design and manufacture of landing gear components for the country's leading airframe manufacturers. Critical landing gear design and construction factors include weight conservation, space limitation, faster and more economical production methods, and the increasing takeoff and landing speeds of modern aircraft.

Since 1943 Menasco has been welding B&W aircraft quality tubing of 4340 steel to various kinds of forged shapes to produce the completed piston or cylinders. Menasco's improved pressure welding, called Uniweld, produces high-quality parts that cannot be produced in a single piece by conventional forging methods. The strength and quality of these Uniweld parts is equivalent to that obtained if it had been possible to produce them in a single forged piece.

For your own equivalent of "the little click that says all is well," insist on B&W Mechanical Tubing. Mr. Tubes, your link to B&W, has the whole story. *Or write for Bulletin TB-361.*

B&W
TUBULAR PRODUCTS DIVISION

THE BABCOCK & WILCOX COMPANY
TUBULAR PRODUCTS DIVISION
Beaver Falls, Pa. and Milwaukee, Wis.: Seamless Tubing, Welded Stainless Steel Tubing
Alliance, Ohio: Welded Carbon Steel Tubing
Milwaukee, Wis.: Seamless Welding Fittings

(Continued from page 31)

485. Precision Castings
16-page booklet includes con and properties of carbon, low allc less, high temperature and tool s cision castings. *Crucible Steel*

486. Protective Coating
Guide to chemicals and proc metal protection. *American Paint*

487. Protective Coating
Two new catalogs on corrosio coating for industrial construc plant maintenance. *Amercoat Co*

488. Pure Metals
Data sheets on vacuum melte copper, iron and nickel. *Vacuum*

489. Pyrometer Calibra
"Pyrometer Thermocouple Ca Data" includes tables of data rel National Bureau of Standards. *B*

490. Pyrometers
Bulletin, "Temperature Indicat basic facts about pyrometry and pyrometers. *Illinois Testing Lab*

491. Pyrometers
32-page thermocouple and bulletin. *West Instrument*

492. Quench Agitation
Information on mixers and including units applicable to i quenching equipment. *Mixing Eq*

493. Quenching
Bulletin 120 on use of heat ex to provide heat control in q bath. *Niagara Blower*

494. Quenching
New bulletin No. 11 on quen also discusses advantages of que tation. *Sun Oil Co.*

495. Quenching
24 page booklet on agitation of ing mediums. Engineering of agi stallations. *U. S. Steel*

496. Quenching Oil
10-page book on new oils quenching process gives results wire quench test and in plant o *Sinclair Refining Co.*

497. Radiography
26-page brochure on very high equipment for radiography and l used. *High Voltage Engineering*

(Continued from page 31)

485. Precision Castings
16-page booklet includes composition and properties of carbon, low alloy, stainless, high temperature and tool steel precision castings. *Crucible Steel*

486. Protective Coatings
Guide to chemicals and processes for metal protection. *American Chemical Paint*

487. Protective Coatings
Two new catalogs on corrosion control coating for industrial construction and plant maintenance. *Amercoat Corp.*

488. Pure Metals
Data sheets on vacuum melted cobalt, copper, iron and nickel. *Vacuum Metals*

489. Pyrometer Calibration
"Pyrometer Thermocouple Calibration Data" includes tables of data released by National Bureau of Standards. *Bristol Co.*

490. Pyrometers
Bulletin, "Temperature Indications", on basic facts about pyrometry and line of pyrometers. *Illinois Testing Labs.*

491. Pyrometers
32-page thermocouple and accessory bulletin. *West Instrument*

492. Quench Agitation
Information on mixers and agitators, including units applicable to industrial quenching equipment. *Mixing Equipment*

493. Quenching
Bulletin 120 on use of heat exchangers to provide heat control in quenching bath. *Niagara Blower*

494. Quenching
New bulletin No. 11 on quenching oil also discusses advantages of quench agitation. *Sun Oil Co.*

495. Quenching
24 page booklet on agitation of quenching mediums. Engineering of agitator installations. *U. S. Steel*

496. Quenching Oil
10-page book on new oils for the quenching process gives results on hot wire quench test and in plant operation. *Sinclair Refining Co.*

497. Radiography
26-page brochure on very high voltage equipment for radiography and how it is used. *High Voltage Engineering*

498. Refractories
24-page booklet on how refractory grain is produced. Chemical and physical characteristics, sizes available, applications. *Norton*

499. Refractory Cement
Bulletin discusses refractories and heat-resistant concrete. *Lumnite Div.*

500. Residual Grinding Stresses
10-page reprint on residual grinding stresses in hardened steel as measured by the deflection method. *Mellon Institute*

501. Resistance Testing
Bulletin 100 on production tester for measuring electrical resistance. *Rubicon*

502. Rhodium Plating
Booklet on rhodium plating as replacement for usual plating metals. *Baker & Co.*

503. Roll Forming
Bulletin 854 on roll forming of cold rolled shapes. *American Roller Die Corp.*

504. Rust Prevention
72-page book on cleaning, preservation, and packaging of metals. Causes of corrosion. *E. F. Houghton*

505. Rust Preventives
12-page bulletin on water-soluble rust preventive. *Production Specialties*

506. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

507. Selective Strippers
Bulletin on materials for selective stripping of one metal from another—electroplated metals, solder or brazing excess. *Enthone*

508. Shotblasting
16-page "Primer on the Use of Shot and Grit". Problems of blast cleaning operations. *Hickman, Williams*

509. Slitting
76-page book on slitting lines for coils and sheets. Design, selection, operation, time studies of operating cycle. *Yoder*

510. Sodium
28-page booklet on using sodium in dispersed form tells how dispersions are prepared and handled, and their advantages. *Ethyl Corp.*

511. Sonic Thickness Tester
Measurement of wall thickness fro one side by sonic method. *Branson*

512. Specifications Index
28-page cross index lists copper allo specifications of nine different Govern ment agencies. *American Brass*

513. Spectrograph
24-page booklet on Echelle spectr graphs. Advantages. Type of work pr duced. *Bausch & Lomb*

514. Stainless Fasteners
52-page book pictures and describes basic fastening devices. Compositio properties, applications and weights stainless steels. *Allmetal Screw Produ*

515. Stainless Steel
12-page booklet on new AM 350 chr mium-nickel-molybdenum stainless st which is hardenable by subzero cooli or double aging. *Allegheny Ludlum*

516. Stainless Steel
Slide chart. Set top at a certain fab cating operation, bottom shows rating each standard grade. On reverse si heat treating and corrosion data a given. *Carpenter Steel*

517. Stainless Steel
Selector gives machinability, physi and mechanical properties, corrosion r sistance of various grades of stainl steel. *Crucible Steel*

518. Stainless Steel
36-page bulletin on effect on propert of processing at different temperatur *International Nickel*

519. Stainless Steels
20-page book on uses of stainless ste *Electro Metallurgical*

520. Steel
256-page handbook lists sizes, weigh lengths, steels available, shapes. Data mechanical properties, standard st compositions, hardness numbers conv sions. *Ryerson*

521. Steel Tubing
48-page Handbook F-3 on fabricat and forging steel tubing. Bending, sh ing, cutting and joining operations scribed. *Ohio Seamless Tube*

522. Stereomicroscopes
38-page catalog D-15 shows value three-dimensional microscopes for ind

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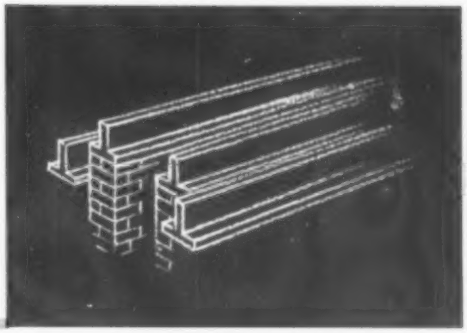

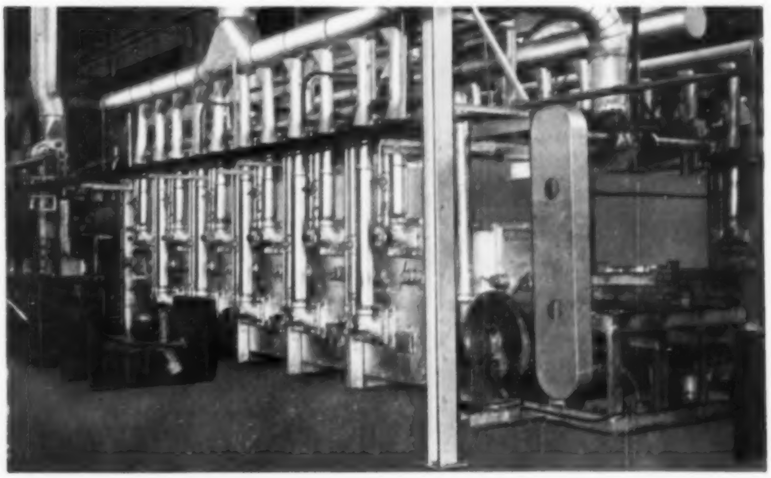

trial assembly lines and research laboratories. *Bausch & Lomb Optical*

523. Sub-Zero Equipment
12-page catalog of chilling machines and temperature testing units. *Cincinnati Sub-Zero Products*

524. Sulphur Determination
New bulletin on high frequency combustion unit for determination of sulphur. *Lindberg Engineering*

525. Surface Alloying
Bulletin on applications of chromizing for heat, wear and corrosion resistance. *Chromalloy Corp.*

526. Temperature Control
Catalog G-20 on differential expansion temperature controls. Electrical and pneumatic types in ranges from sub-zero to 1800° F. *Burling Instrument Co.*

527. Temperature Control
4-page data sheet on electro-pneumatic controllers. Specifications, standard ranges, equipment for complete control system. *Leeds & Northrup*

528. Temperature Conversion
16-page temperature conversion booklet and electromotive force of thermocouple alloys in absolute millivolts. *Wheelco*

529. Temperature Conversion
Chart converts degrees Fahrenheit to Centigrade and vice versa from −400 to 4000° and shows range of sensing elements. *Thermo Electric*

530. Temperature Measuring
8-page catalog 175 on optical, micro-optical, radiation, immersion and surface pyrometers. *Pyrometer Instrument Co.*

531. Tempilstiks
"Basic Guide to Ferrous Metallurgy", a plastic laminated wall chart in color. *Claud S. Gordon*

532. Test Accessories
22-page Bulletin 46 on instrumentation, tools and accessories for mechanical testing machines. *Tinius Olsen*

533. Test Specimens
Data on machine for cutting test specimens to ASTM specifications. *Sieburg Industries*

534. Tester
Bulletin 164 on Dyhedron, dynamic diamond tester for hardness and lubricity of materials. *Taber Instrument*

535. Testing Machines
8-page folder on Amsler machines for tests in tension, compression, torsion, shear, fatigue, bending and ductility. Bulletins on wear testing, and testing of miniature samples. *Buehler*

536. Textured Metal
16-page booklet on advantages and applications of textured metal. *Rigidized Metals*

537. Thermocouple Tubes
New 4-page bulletin on standard thermocouple protecting tubes and wells. *Claud S. Gordon*

538. Thermocouple Wire
12-page bulletin No. 1701 lists conductor specifications, insulations for various operating temperatures. *Revere Corp.*

539. Thermocouples
44-page catalog EN-S2 describes couples and assemblies for general application and for special plant and laboratory uses. Tabular data on accuracy and limits of couples. *Leeds & Northrup*

540. Thermostat Metals
Chart compares properties of thermostat metals produced by various manufacturers. *American Silver Co.*

541. Titanium Alloy
Data on ternary alloy with 3% aluminum and 5% chromium gives physical properties, forging temperatures, high temperature characteristics. *Mallory-Sharon Titanium*

542. Titanium Tubing
Bulletin No. 42 on properties, applications and advantages of titanium tubing. *Superior Tube Co.*

543. Tool Steel
New 44-page book on tool steels for the nonmetallurgist explains the six basic kinds of tool steels and their heat treatment. *Crucible Steel*

544. Tool Steel
Folder on high-carbon, high-vanadium tungsten-base high speed steel. *Latrobe*

545. Tool Steels
Bulletin on tool steels, hot work specialty steels, bar stock, billet, sand casting, drill rod, flat ground stock and tool bits. *Darwin & Milner, Inc.*

546. Tukon Tester
12-page bulletin DH-114 on Tukon micro and macro hardness testers. *Wilson Mech. Inst.*

547. Ultrasonic Cleaners
Bulletin on ultrasonic cleaners for instruments. Advantages of use in manufacturing, maintenance and reconditioning. *Pioneer-Central Div.*

548. Vacuum Coating
Bulletin on principles, production steps, applications, equipment. *National Research*

549. Vacuum Gages
32-page Catalog 7001 on gages for vacuums to 10^{-11} mm. Hg and pressures to 150,000 psi. *Minneapolis-Honeywell*

550. Vacuum Melting
8-page bulletin on production and testing equipment for vacuum melting. Advantage. *Utica Metals Div., Utica Drop Forge & Tool*

551. Vacuum Systems
Booklet on vacuum drying, impregnation, metallizing, pumping systems. *Stokes*

552. Welding
16-page catalog 2350 on equipment for inert-gas shielded metal arc welding process. Manual and automatic units. *Air Reduction*

553. Welding Copper
24-page booklet on oxyacetylene, carbon-arc and metal-arc welding techniques for copper and copper alloys. *Revere*

554. Welding Electrodes
50-page book on electrodes of stainless, mild and high-tensile steels, cast iron, nonferrous alloys, low-hydrogen and hardfacing compositions. *Air Reduction*

555. Welding Electrodes
Report No. W5410 on low hydrogen electrodes for high alloy steels. *Harnischfeger Corp.*

556. Welding Equipment
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

557. Welding Magnesium
Various welding processes for magnesium, stress relief and recommended procedures. *Brooks & Perkins*

558. Wire Mesh Belts
130-page manual on conveyor design, belt specifications, metallurgical data. *Cambridge Wire Cloth*

559. X-Ray Equipment
Bulletins on No. 2 SPG X-ray detector describe specifications and advantages. *X-Ray Dept., General Electric*

FEBRUARY, 1956

283	307	331	355	379	403	427	451	475	499	523	547
284	308	332	356	380	404	428	452	476	500	524	548
285	309	333	357	381	405	429	453	477	501	525	549
286	310	334	358	382	406	430	454	478	502	526	550
287	311	335	359	383	407	431	455	479	503	527	551
288	312	336	360	384	408	432	456	480	504	528	552
289	313	337	361	385	409	433	457	481	505	529	553
290	314	338	362	386	410	434	458	482	506	530	554
291	315	339	363	387	411	435	459	483	507	531	555
292	316	340	364	388	412	436	460	484	508	532	556
293	317	341	365	389*	413	437	461	485	509	533	557
294	318	342	366	390	414	438	462	486	510	534	558
295	319	343	367	391	415	439	463	487	511	535	559
296	320	344	368	392	416	440	464	488	512	536	
297	321	345	369	393	417	441	465	489	513	537	
298	322	346	370	394	418	442	466	490	514	538	
299	323	347	371	395	419	443	467	491	515	539	
300	324	348	372	396	420	444	468	492	516	540	
301	325	349	373	397	421	445	469	493	517	541	
302	326	350	374	398	422	446	470	494	518	542	
303	327	351	375	399	423	447	471	495	519	543	
304	328	352	376	400	424	448	472	496	520	544	
305	329	353	377	401	425	449	473	497	521	545	
306	330	354	378	402	426	450	474	498	522	546	

METAL PROGRESS,

7301 Euclid Avenue, Cleveland 3, Ohio

Please have literature circled at the left sent to me.

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Company

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City and State

Postcard must be mailed prior to May 1, 1956.
Students should write direct to manufacturers.

ALLIED

New Lindberg electric furnace with CORRTHERM element at Allied Metal Treating Corporation, Kenosha, Wisconsin. This furnace is used 24 hours a day, 6 days a week, for carbonitriding, clean hardening pinion gears, hardening crank shafts after carburizing and carburizing small gears and shafts.

EKLUND

Installation of new Lindberg furnace with CORRTHERM electric element at Eklund Metal Treating, Inc., Rockford, Illinois. Furnace used 24 hours a day, 7 days a week, for carburizing gears and machine tool parts, carbonitriding sheet metal screws and automotive parts, and hardening and tempering bolts.

PERFECTION

Lindberg electric furnace with CORRTHERM element just installed at Perfection Tool & Metal Heat Treating Company's Lombard, Illinois plant. This furnace is being used 24 hours a day, 6 days a week, for carbonitriding and carburizing parts for automotive and farm implement industries.

New life for old drums . . . thanks to GAS

Here at the Prime Drum Corporation in Norfolk, Virginia, old steel drums are refurbished in a series of Gas heat processes. The drums are stripped of rust and foreign matter in a caustic soda solution heated by Gas. They are then neutralized in water, and dried prior to painting.

Gas heats the water, drys the drums, bakes the paint. Throughout the entire process, Prime Drum relies on Gas. It provides the speed needed to eliminate lengthy waits for the solutions to reach the desired temperatures.

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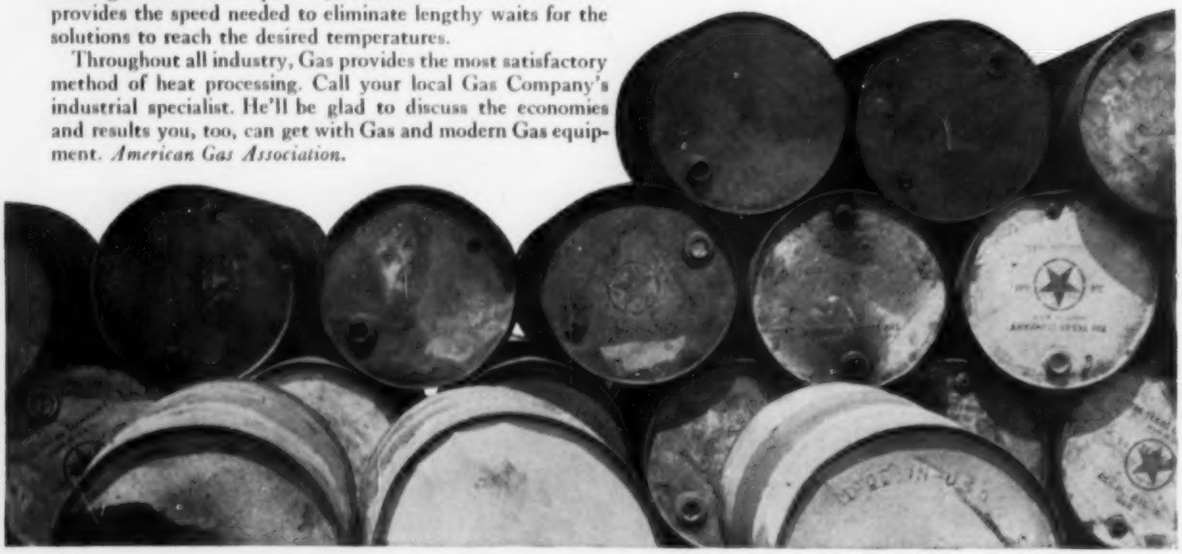

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Yield Strength — 40,000 psi

Elongation — 30%

Hardness — 160 BHN

Endurance Limit — 40,000 psi

Creep Strength — Stress for 1% elongation in 10,000 hours at 1300F-1300 psi

Resistance to Scaling — Suitable for continuous service to 1600F.

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CRUCIBLE first name in special purpose steels

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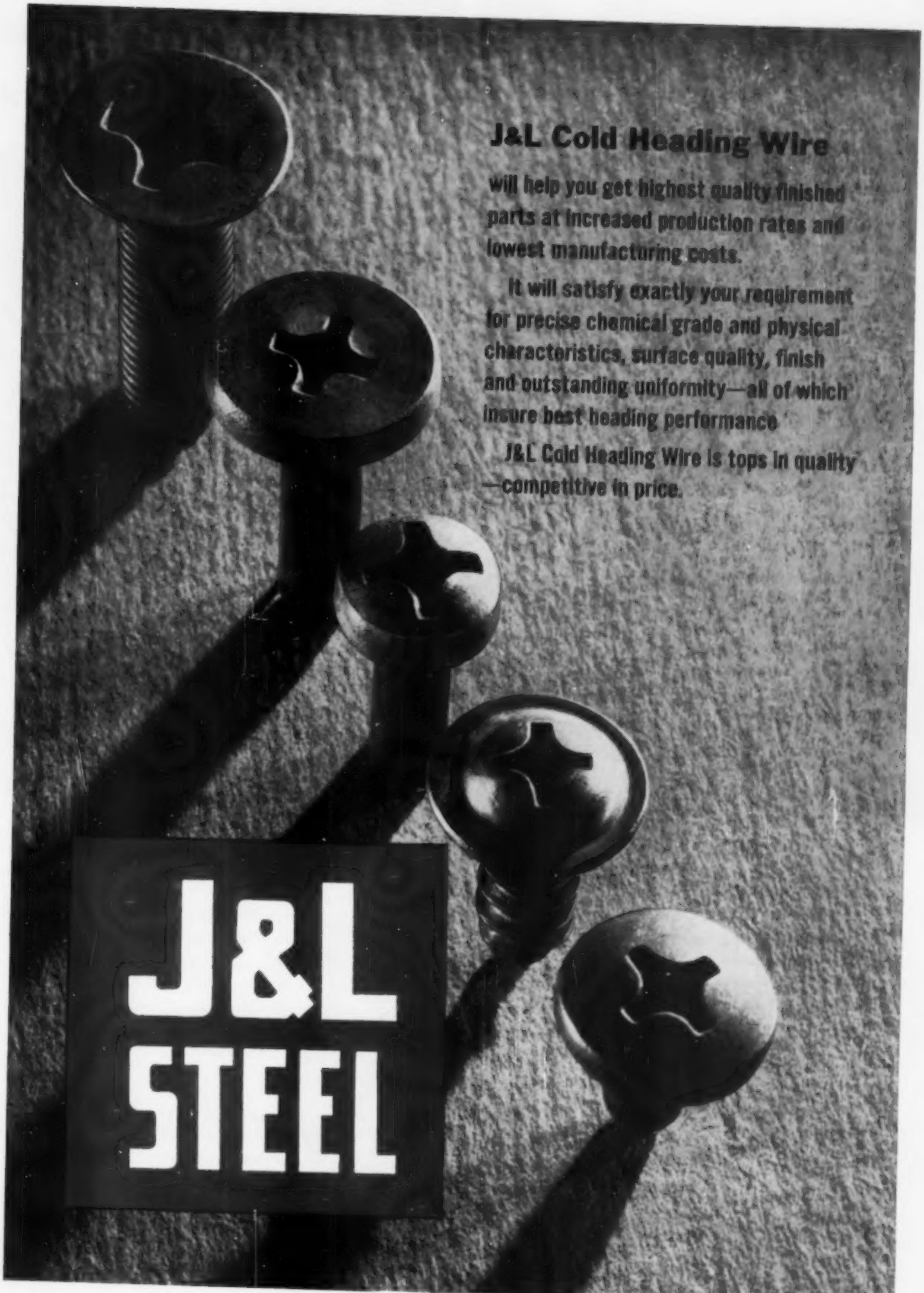
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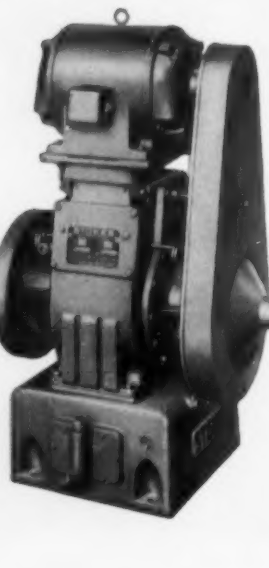

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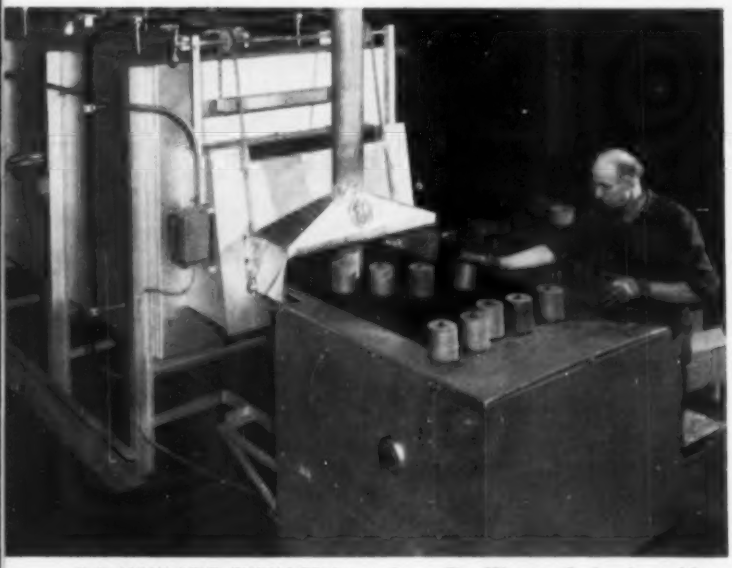

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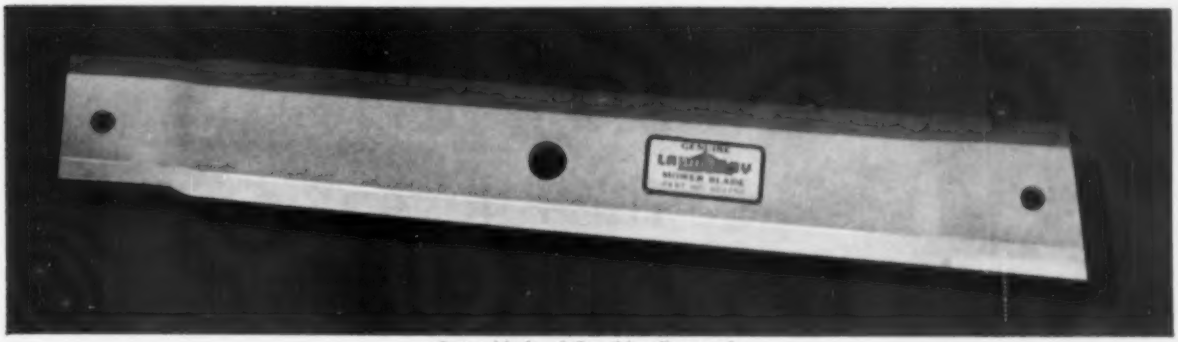

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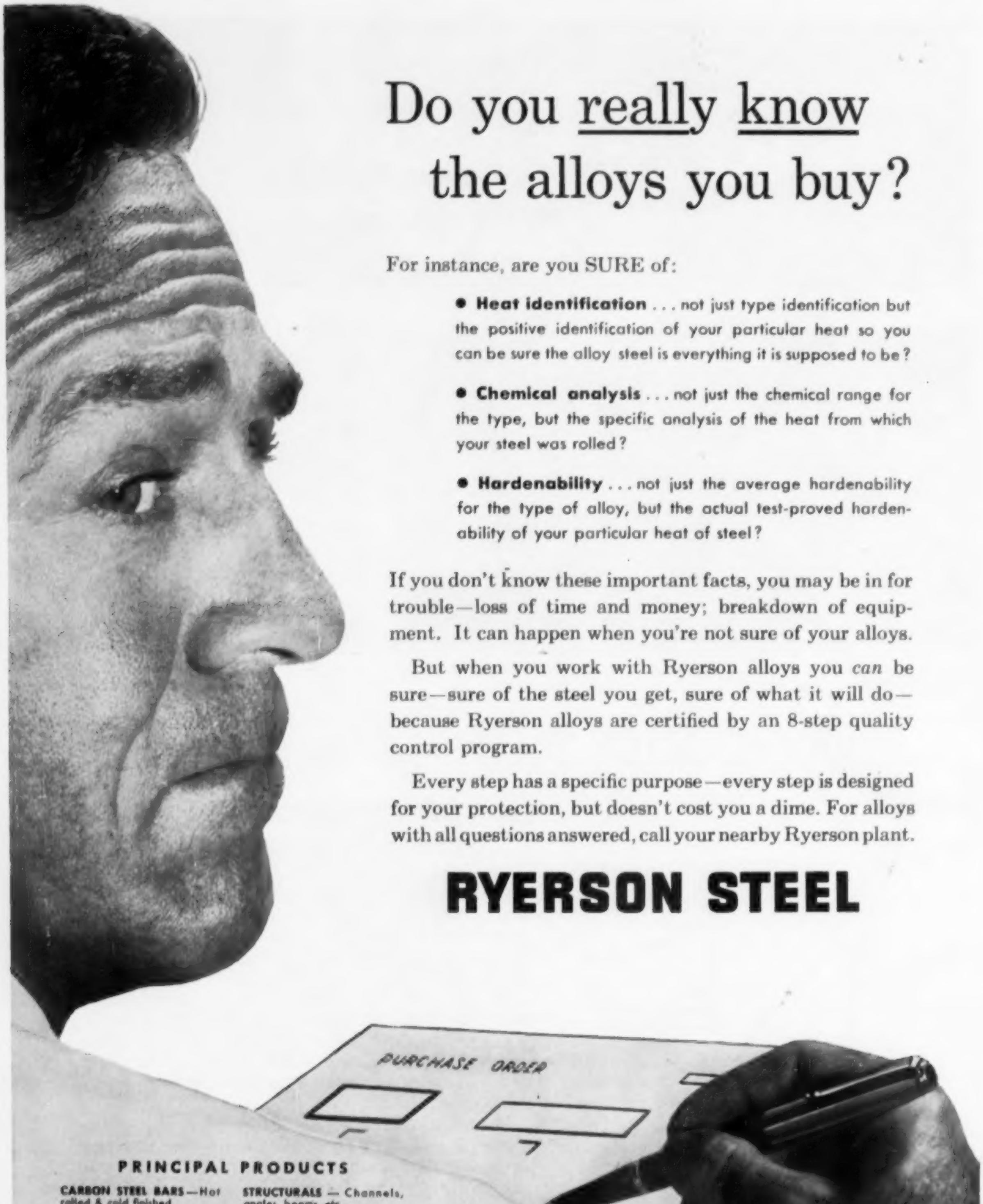

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Metal Progress

Volume 69, No. 2 February, 1956

Recent Accidents With Large Forgings

*A Report by E. E. THUM**

A half-century of almost perfect performance of large electrical machinery has been broken by four failures of massive rotor forgings since early 1953. A day-long discussion of the causes and preventive measures at the Diamond Jubilee Meeting of the American Society of Mechanical Engineers reveals that two failures were due to unduly high stress concentrations introduced by the design or by a repair, and two others were due to misinterpreting or minimizing the evidence of internal defects found by ultrasonic inspection. (S 21, S 13, Q 25, ST)

ONE DAY early in January of 1953 one of the 125,000-kw., 1800-rpm. steam turbines at Tanners Creek Station of Indiana & Michigan Electric Co., in service about two years, suddenly started vibrating violently. The unit was immediately shut down, and on opening the intermediate-pressure casing half of the rim of one of the turbine wheels was found broken away. The station was not damaged other than by a moderate fire from escaping lubricating oil.

On March 4, 1954 a completely finished generator rotor burst into a large number of fragments while being tested in the "precision balance pit" in the manufacturer's plant. This was intended for Arizona Public Service Co., and was to run at 3600 rpm. and generate 147,000 kva. Failure occurred at about 3400 rpm.

On Sept. 17, 1954 a similar rotor, after only three months' service at the Cromby station of Philadelphia Electric Co., burst just after a week-end shut down. The machine was designed to generate 216,000 kva. and operate at 3600 rpm.; the accident occurred at 3780 rpm. while speed was designedly increased to check the overspeed trip. It had previously safely endured two such overspeed runs to 3950 rpm. All damage was confined within the casing, except for a small fire in the lubricating system.

Then on Dec. 19, 1954 a catastrophe at Ridgeland Station in Chicago of the Commonwealth Edison Co. caused the devastation in Fig. 1.

*Editor, *Metal Progress*, Cleveland

Fig. 1 – Ridgeland Station After Accident. (Courtesy Allis-Chalmers Mfg. Co.)

The entire low-pressure turbine spindle exploded into four quadrants and several smaller fragments during routine overspeed-trip test. The entire cross-compound unit was designed for 165,000 kw., and the low-pressure turbine to run at 1800 rpm. The unit had been in service only four months.

This amazing run of hard luck costing lives, injuries and much money, suddenly plaguing an industry with a 50-year history of almost perfect performance, has understandably started intensive investigations from many angles, some of which were reported to a day-long conference at the American Society of Mechanical Engineers' diamond jubilee meeting in Chicago.* Since the turn of the century there has been consistent

*"Turbine Wheel Fracture at Tanners Creek", Paper No. 55-A-210, by A. W. Rankin and B. R. Seguin.

"Investigation of Large Steam-Turbine Spindle Failure", Paper No. 55-A-172, by H. D. Emmert.

"Acceptance Guides for Ultrasonic Inspection", Paper No. 55-A-194, by A. W. Rankin and C. D. Moriarty.

"Report of Two Generator Rotor Fractures", Paper No. 55-A-208, by C. Schabtach and associates.

"Work of the Task Group on Brittle Failure of Large Steel Forgings", Paper No. 55-A-209, by A. O. Schaefer.

"Large Rotor Forgings", Paper No. 55-A-215, by R. E. Peterson and associates.

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growth in the size and capacity of turbines and generators. For example, inlet steam temperatures have crept up from 350 to 1100° F. and pressures from 150 to 5000 psi.; capacity of single units from 400 to 275,000 kw. on a single shaft. Speed of the large rotor forgings, which may be up to 7 ft. diameter, is 1800 rpm., and even 3600 rpm. for the smaller diameters needed for high-pressure stages. Direct coupled electric generators, of course, run at the speed of the turbine.

This enlargement in size and capacity and efficiency has been accompanied by continuous cooperation between American electrical manufacturers and the producers of large forgings. Literally thousands of such units have been built. Failures in operation have been very rare; when they have occurred, however, an intensive effort to find the cause has always resulted in improved design, construction and operating practices. Such continuous progress certifies that in almost every instance the designs have been safe, the steel well made and adequate for operational loads, inspection has been searching, and proper safety devices provided.

Then why this series of four failures of the Tanners Creek, "Arizona", Cromby, and Ridgeland machines?

Tanners Creek – The turbine wheel which failed at Tanners Creek was an integral part of a large forging of a 1.02-1.13-0.27 Cr-Mo-V steel with 0.36% C and 0.25% residual nickel. Hydrogen was 0.00005% by weight (unusually low), nitrogen 0.005 and oxygen 0.006. The forging was made from an acid openhearth steel ingot; rough machined it was 19 ft. long, 61 in. max. diameter, and weighed 72,000 lb. All the normal tests for quality control were passed successfully by this forging; after the failure at the rim no evidence of poor steel quality could be found by microscopic examination. The fracture in operation apparently started in metal between two 0.250-in. holes in the rim where the notch blade is pinned on (Fig. 2). Calculated tangential stress at the outside diameter of the wheel was 5500 psi. but between the two pinholes it averaged 14,000 psi. (as determined by photo-elastic model). Heat treatment* was such that about 10,000 psi. residual stress existed. Centrifugal rim tension of 5500 psi. must now be added, giving an estimated average stress of 35,000 psi. This is very close to the 16,000-hr., 960° F. rupture strength of this steel.

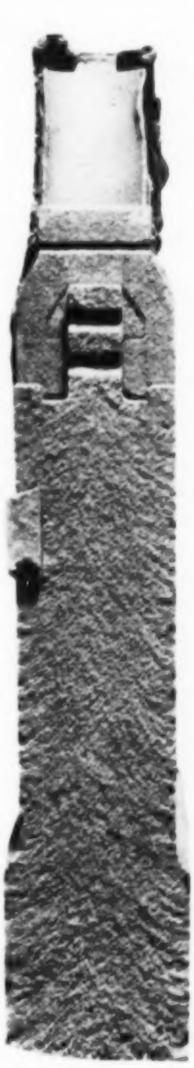


Fig. 2 – Fracture Face of Tanners Creek Turbine Wheel; Fracture Apparently Started at Holes in Notch Opening in Wheel Rim. (Courtesy General Electric Co.)

Since this method of attaching buckets has been in widespread and successful use for over 25 years, and since another one of the seven units of identical design had accidentally run at 50% overspeed without damage, the investigators believe the design is not marginal. Stress-rupture tests at 1000° F. on metal from the broken wheel show quite low figures for elongation (1 to 2%) instead of the expected range of 2 to 10% for the alloy composition and heat treatment. Consequently this deficient ductility or plasticity under working conditions, aggravated by the tri-axial stress system in the metal between the pinholes, is blamed for the failure. However, even the expected plastic flow at this point would not reduce the residual stress by any significant amount. An added consideration is the possibility of a sudden drop of 125° F. in steam temperature, giving transient thermal stresses on the order of 13,000 psi. additional.

Messrs. Rankin and Seguin of the Large Steam Turbine-Generator Department of General Electric Co. believe the failure was due primarily to the addition of residual stresses from heat treatment to the expected centrifugal stresses and the thermal stresses due to sudden changes in steam temperature. A possible contributing factor, in their opinion, is low rupture elongation of the steel at working temperature. They venture

*A very complicated program extending over 400 hr. between forging and rough machining, and 350 hr. between rough machining and delivery. The latter consisted essentially of solution treatment at 1850°; rapid (air) cool to 1000° and then slowly to 600° for a long equalization; then reheating and soaking ("tempering") at 1225° and furnace cooling.

no opinion as to the reason why this particular rotor – one of seven presumably identical, within commercial limits – was deficient in this quality at this highly stressed region.

"Arizona" – The generator rotor that was intended for service in Arizona but broke in the manufacturer's test pit was from a 212,000-lb. basic openhearth ingot, forged down about 3 to 1 in cross section and rough machined into a cylinder 39 in. in diameter by 15 ft. long, plus about 7 ft. of shaft of relatively small diameter at each end. A small-bore hole was drilled down the axis, end to end. Ultrasonic inspection of the large central mass of metal showed numerous indications ranging outward from the bore, and the bore was successively enlarged four times to a final 5⅜ in. without finding anything except "harmless slag inclusions". This center bore in the 39-in. diameter portion was later filled with shrink-fit plugs to restore the needed magnetic capacity. This induced moderate stresses (on the order of 8000 psi.) at the bore's surface, but these should have been largely relieved by rotation at normal speed.

The metal was a 2.50-0.55 Ni-Mo steel, 0.32% C, 1.0% Mn, 0.06% V, and with 0.05% tramp Cr. Room-temperature tensile tests were well above specifications. After the accident it was found that some radial test pieces cut from metal within 6 in. of the bore had 5 to 7% elongation and 4 to 6% reduction of area, compared with the specified minima (13 and 22% respectively) possessed by many others. Heat treating program stretched over 350 hr. from stripping of ingot to start of forging, and 715 hr. after forging, plus 175-hr. stress-relief during the operation of plugging the center.

Fig. 3 – Distinctive Circular Mark, Actual Size, on Primary Fracture Surface of "Arizona" Rotor. (Courtesy General Electric Co.)

Numerous fractured surfaces contained flat, circular areas of coarse-grained, slightly harder metal, but free of porosity and inclusions, as shown in Fig. 3. Ultrasonic tests on large fragments gave indications which, when opened up, had this same appearance. Etched cross sections also show cracks, edge-on, more or less in line with darkly etching lines of "segregate" – streaks of martensite or fine bainite.

Mr. Schabtach and his associates at General Electric Co. believe that these are thermal cracks induced by transformation stresses, probably coupled with embrittling effects of the hydrogen in the metal, that they existed in the forging upon delivery from the steel mill, and that the unusually large number of ultrasonic indications from this forging were due to these cracks rather than to slag inclusions as had been supposed by the inspectors.

Fig. 4 – Macrosection (Etched) Showing Segregation Lines, Half Size

Cromby – The Cromby rotor was one of 16 others of the same size placed in operation during the past two years – the largest generator rotors ever made in this country. They reach only mild temperatures, the heat being mainly due to resistance to electrical currents in the windings. It was of acid openhearth steel, the ingot being hot-topped with a basic electric steel heat. Steel analysis was very similar to the Arizona rotor; the ingot was an 82-in. octagon and had quite small variation or segregation of carbon, sulphur

and phosphorus, center to edge. The finished forging was 36 ft. long, 43 in. diameter in body, and weighed 118,000 lb. Ultrasonic inspection gave excellent results; mechanical properties well exceeded specification minima, and metallographic examinations after the failure showed uniform and normal mixture of acicular ferrite and bainite, surface to bore, of A.S.T.M. grain size 7.

When the coil slots were being cut, a milling cutter broke and damaged the big forging. Repairs were made by drilling a series of overlapping threaded holes and screwing studs into them. The fracture in service apparently started at the bottom of one of these holes and progressed inward to the bore, splitting the rotor longitudinally into halves almost instantaneously before fragmenting further. There was no evidence of fatigue failure.

The stress concentration of about 7.6 times normal or designed loading at the bottom of the conical hole is clearly to blame for this accident. Many other rotors repaired in this way are in long and successful service, but about nine rotors whose stress concentration approaches the 7.6 of the burst one have been replaced. Their computed stress at such points is almost identical to the tensile strength of the material.

A curious accumulation of segregation bands running in axial direction was found in the steel immediately adjacent to the stud-hole bottoms. Figures 4 and 5 show these in macro and micro sections, indicating gray sulphide inclusions within ferrite islands and a matrix of higher carbon bainite. X-ray emission techniques showed the following concentration ratios of elements in comparison with surrounding areas: C 0.9 times; S 1.6, P 1.9, Si 1.4, Mo 1.6, V 1.7, Cr 1.1, Mn 1.0, Ni 1.1. This 50% (more or less) increase in alloy content is responsible for a hard spot, and the investigators have suggested that this hardness and its associated brittleness may have helped to start the crack.

Mr. Schabtach and his associates therefore conclude that the failure originated from stress concentrations at the stud holes but that the rotor might have survived well had not the metal contained hard, brittle areas of alloy concentration, deficient in ductility.

Ridgeland – Figure 6 is an outline drawing of the low-pressure turbine spindle, disk and blade assembly of the Ridgeland unit, one of five machines of this design. The spindle was made from a 108-in. ingot weighing 372,000 lb. Heat treatments on the completed forging took 470 hr. After rough machining it was double normalized at 1640 and 1600° F., tempered at 1180° and slowly cooled. This took 380 hr. more. The steel was a complex alloy specified as C 0.25 to 0.35%, Ni 2.50 to 3.50, Cr 0.25 to 0.75, Mo 0.40 to 0.60, V 0.05 min. Tensile tests were satisfactory, but borescope inspection showed discontinuities in one end, so the bore was enlarged from the original 8 in. to 16 in. as shown in Fig. 6, and visual

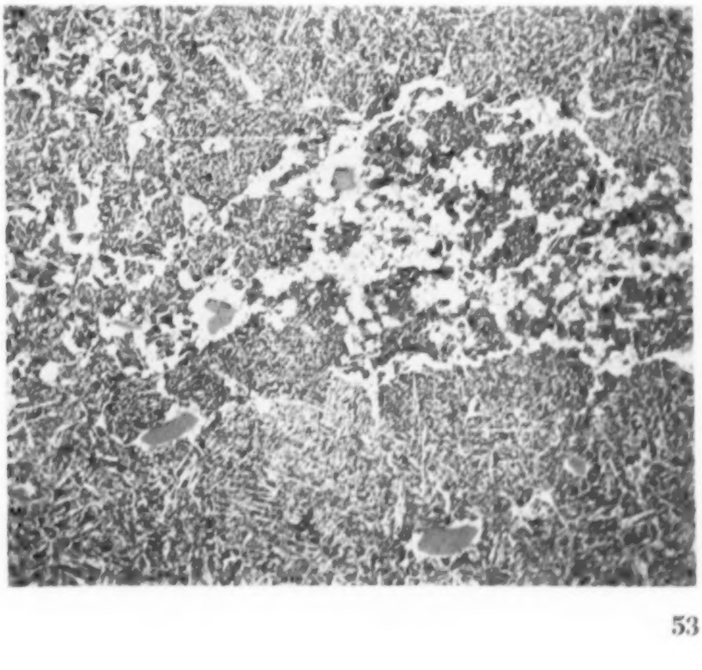


Fig. 5 – Transverse Microstructure at and Around Segregation Line. 75 ×

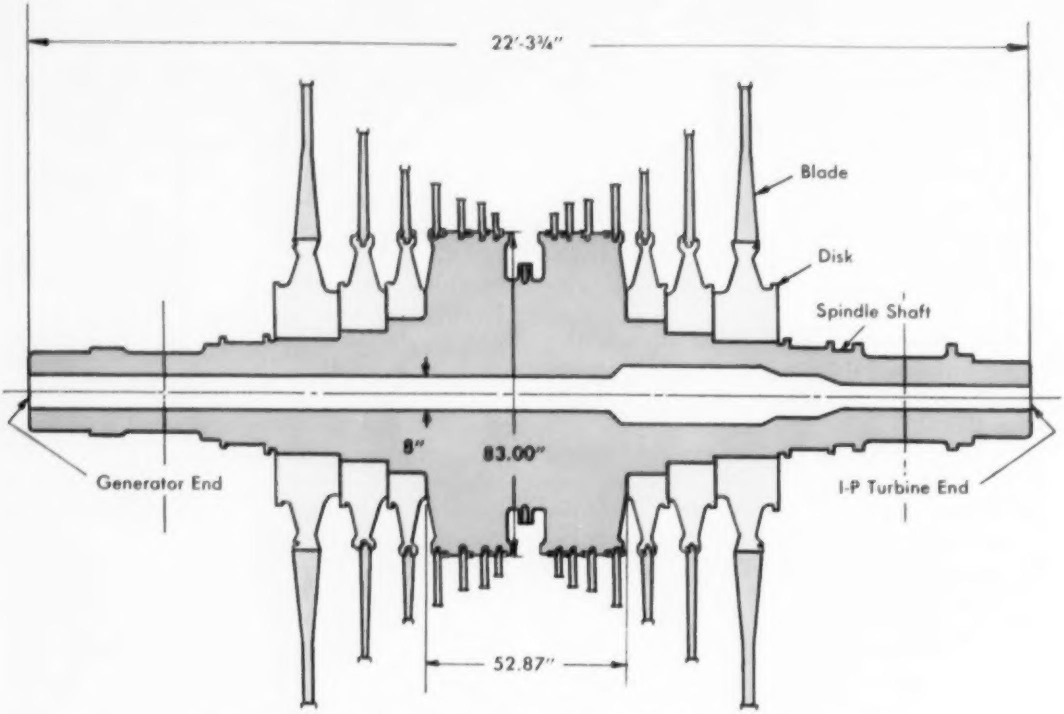


Fig. 6 – Low-Pressure Turbine Spindle of Ridgeland Turbine. Main body of forging, 83 in. diameter by 53 in. long, burst into quadrants

examination then showed no defects on the bore. Ultrasonic tests disclosed an area within the main body reflecting indications of variable intensity, but the forging could not be rejected on the basis of ultrasonic tests – a provision written into the specification by the steelmaker.

Design is based on average tangential stress due to centrifugal load of blades plus mass of the shaft. (This is authorized by U.S. Navy and American Bureau of Shipping, and conforms to results of many bursting tests on miniature rotors.) For this turbine this stress at 1800 rpm. equals 19,660 psi. in the main body. With a normal factor of safety of four, this indicated a steel whose tensile strength should be at least 80,000 psi., and yield at least 60,000. Minimum properties of test pieces from the forging were:

Tensile strength	11,000 psi.
Yield strength	85,000
Elongation	19.0%
Reduction of area	50.8

The heat treated and rough machined shaft was dimensionally very stable, as proved by rotating slowly for 30 hr. while at 950 to 1100° F.

After four months' service the disaster shown in Fig. 1 occurred. Intensive study and bursting tests on models have reconstructed the sequence of fracture as indicated in Fig. 7. The initial crack was in a coarse-grained mass of steel near the bore, and it extended in a small fraction of a second toward both ends, tending to split the main body neatly into two halves. This crack was stopped by the clamping action of the shrunk-on rings, but this set up overwhelming stresses at the fillet corners, and cracks ran inward in a diagonal direction, meeting near the bore. Strong centrifugal forces in the halves of the main body then split each in two, and the four quadrants flew out like enormous projectiles. The remaining conical segments attached to each spindle-end then furnished a number of smaller missiles.

One of the large quadrants was sawed longitudinally and smoothed. Magnetic particle inspection showed numerous cracks from near the center bore out to about mid-radius; these cracks were several inches long and an inch deep, and they followed the pattern of the forging lines. The same pattern was shown on a sulphur print. This was judged to be typical of flakes or of thermal cracks. Test bars from near the bore also had deficient ductility; the fractures frequently contained "fish-eyes", thought to be spots embrittled by hydrogen concentrations – that is to say, incipient flakes. Finally the ultrasonic surveys of such fragments showed indications of

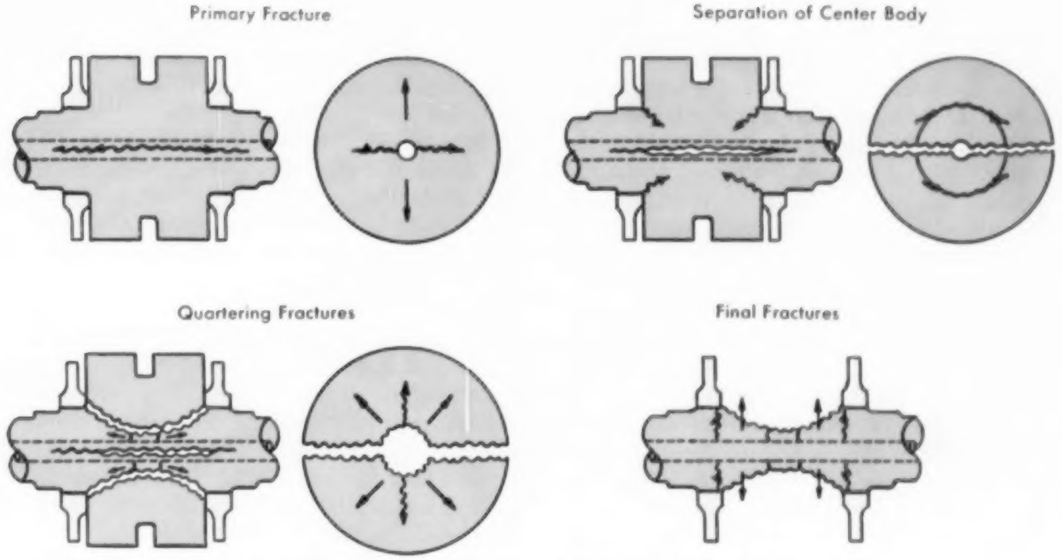


Fig. 7 – Sequence of Failure of Ridgeland Rotor Forging

the same general nature as those originally found in the rough machined forging before it left the steel plant.

Mr. Emmert of Allis-Chalmers concludes that the steel was full of flakes (tiny cracks) and was also of such nature that it could not arrest a crack, once it started to spread from such a sharp notch. This notch sensitivity cannot be predicted from the ordinary tensile test. He suggests that Charpy tests at various temperatures are more revealing. The steel in this particular rotor (as well as in the Arizona and Cromby rotors) had a transition temperature from tough to brittle fracture somewhat *above* the working temperature, as shown in Fig. 8.

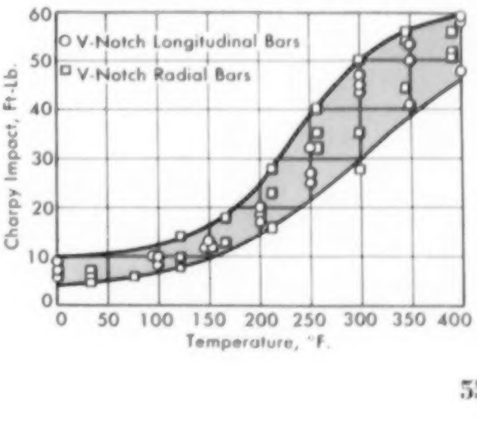
Commentary

These recent failures, together with some other incidents where cracked forgings were discovered during periodic inspection, are responsible for the very cautious way in which the electrical industry has approached the problem of bigger and faster generating equipment. Three American manufacturers of such equipment – General Electric, Westinghouse and Allis-Chalmers, joined whole-heartedly by five steel companies – are intently studying the problem, using not only scale models but also some full-sized forgings made by various steelmaking methods (including one rotor from abroad). Work of this sort may help interpret the results from our standard laboratory test pieces or devise new ones, so the action of larger masses of metal (inevitably constrained by multi-axial stress systems) may be forecast.

Steelmaking – A theoretical cure for all these troubles is to make flawless metal and operate it at loads below its limit of endurance. Even though flawless metal is an unattainable idea, it is easy for a nonmetallurgist to blame the metal for any failure. It is not so easy for the nonmetallurgist to prescribe the cure. In fact, the steelmaker himself can hardly prove unmistakably why one process seems to make "better" steel than another. It is also well known that what is "better" for one product is not so good for another, especially when they get to outsize articles such as these rotors, large pressure vessels, or large rigid (welded) structures.

For example, the bessemer process makes ex-

Fig. 8 – Charpy Impact Tests From Mid-Radius of Main Body of Ridgeland Rotor



cellent screw-machine stock, despite a high nitrogen content which would embrittle a heavy rail. The basic electric furnace can make "better" tool-steels and high-alloy steels than the basic open-hearth, but only if great care is exercised in the melting, refining and pit practices. About the only way we know to minimize the inevitable segregation of complex constituents (other than make *pure* iron, which is weak) is to make clean steel, cast it into relatively small ingots, and control grain size chiefly by regulating the solidification rate. That knowledge doesn't help much when the forging requires a 200-ton ingot, 9 ft. in diameter.

Again, while no one (as far as the Editor knows) has been able to find the cause of occasional mammoth grains of metal in large forgings, acid openhearth steel is commonly regarded as being much less susceptible to "flakes" than basic steel. Since both have the same composition in the end, it probably isn't because the acid steel starts off with low-phosphorus raw material. The steelmaker says it's due to the refining methods which, in acid furnaces as in the old crucible process, result in a "more highly deoxidized and degasified metal". Yet now comes news from Austria that pig iron refined completely with an oxygen jet produces steel in large tonnages which not only has superior toughness and low transition temperature, but also has that ability to stop the propagation of a crack which is as essential for rigid welded structures as it is for large forgings.

Mention was also made at the A.S.M.E. meeting about hydrogen in the unfortunate forgings – hydrogen, that convenient whipping boy of the 1950 decade. Hydrogen analysis in one of these forgings is lower than one part per million, and as Mr. Schaefer of Midvale Co. said in his contribution, methods of sampling and gas analysis are far from precise, and no one can say what the dangerous level of hydrogen is. Vacuum melting was also mentioned – although it can at present make only comparatively tiny ingots. The superior stress-rupture strength and ductility which vacuum-melted superalloys for turbine buckets possess, in comparison with the same alloy produced in a conventional electric furnace, is due not only to low hydrogen and fewer "dangerous" inclusions, but also in all likelihood to lower oxygen, nitrogen and numerous volatile metals present in such small traces they are not suspected nor analyzed for. Under these circumstances, and in view of the meticulous care required for vacuum steel, the German scheme of casting molten steel made in open furnaces into an evacuated ingot mold does not seem to offer much hope because of the short time the metal is protected or evacuated.

This commentator noted frequent mention by the mechanical engineers and ultrasonic testers of "harmless nonmetallic inclusions", and wondered about a "harmful" inclusion. A friendly steelmaker, sitting alongside, said that nonmetallics are regarded as harmless since all rotor forgings – indeed all commercial steels – have numberless inclusions, and their number rises with the magnification of the searching microscope. Since these forgings and steels are sturdy, most inclusions must be harmless. Possibly the difference between a harmless and a harmful inclusion is that a harmless one is small and roundish and in metal which is not working close to the endurance or elastic limit, whereas a harmful one is thin and sharp edged – a real stinker of a stress-raiser. It would appear that another potentially dangerous discontinuity is the alloy segregate shown in Fig. 4 and 5 – high-alloy spots whose delayed transformation throws large stresses into the surrounding rigid metal, and whose inherent hardness is associated with brittleness and deficient plasticity.

Undoubtedly the art of steelmaking and heavy forging has progressed steadily through the years – but has it gone far enough? It is unthinkable that anything would be done which might jeopardize the acceptability of these valuable masses of metal. Yet it might be questioned whether the present more-or-less conventional analyses are the best that can be devised. (The Editor is assured that nothing has been trimmed from a desirable alloy content in order to save "strategic" metals.) Is vanadium the best grain-refining element available? Can liquid quenching be used in some steps of the heat treatment with safety and advantage, and what are the limitations? Can an alloy be designed strong enough for generator rotors which is low-carbon ferrite (magnetic), strengthened sufficiently by solid solution elements and free from transformations and resulting large internal stresses? What are the essential items in process or product necessary to insure a steel that resists the starting of a crack at some stress raiser and also is able to stop it before it gets very far? Perhaps some of these questions may be answered from the tests on full-sized rotor forgings now under way. More likely they will have to await more discerning test methods on *small* pieces which will accurately predict the action of huge masses of metal. The

developmental work will have to be done on small heats rather than on 200-tonners.

Inspection and Design – After acknowledging that metallurgists, in spite of their best efforts, still are human beings and always will produce something short of the ideal, it must in all fairness be said that the designers and operators also must stop, look and listen. In retrospect it can be said that the ultrasonic warnings given by two of these burst rotors were not heeded. For this reason it is not surprising that inspection methods are under closest scrutiny.

For example, Messrs. Rankin and Moriarty of General Electric Co., with a background of tests on about 1500 large rotors, reinforced by destructive tests on rejected forgings, have devised a scanning technique whereby sending and receiving crystals are traversed slowly along a cylinder while it is being rotated in lathe centers. In this equipment "stationary" indications are from predominantly tangential defects, whereas "travelling" indications – those which move backward and forward – are predominantly radial in their extent. Each such reflection is graded as to magnitude (percentage of reflection from the bore), they are arranged statistically in groups, and total number of indications is plotted against size of indication. The results build up into Fig. 9.

Of the 1500 forgings under survey, 62% had no ultrasonic defects big enough to give reflections larger than 5% of the bore's. Of the 27% whose indications plotted to the left of the "inner line", on Fig. 9, none were found to be cracked. Of the 5% (or 75 rotors) which plotted between the "inner" and the "outer line", three were found to be cracked after trepanning the "traveling" indications. Of the 6% (or 90 forgings) which plotted to the right of the "outer line", one third were proved to contain cracks.

Had this system of inspection and interpretation been in use in 1953, the Arizona rotor probably would not have been accepted, since its ultrasonic record is far into the danger zone.

Norman Mochel of Westinghouse Electric Corp. also recommended highly the plan of repeating the ultrasonic survey on large rotors during periodic shutdowns, and comparing the results with records of the forging before it started operation. This is almost standard practice on high-head impulse water wheels and (at least in one Western railroad) on motive power.

Finally he called attention to alternative methods of construction for seven 165,000-kw., 1800-rpm. turbines where the rotor, if made as in Fig. 6, becomes too large for comfort and for economical production, considering the possibility of rejections from internal unsoundness. Westinghouse has reverted to earlier designs where the shaft is relatively small and each group of turbine blades is fixed to the periphery of shrunk-on disks. In some high-speed rotors of European manufacture the wheels or disks are welded to the shaft. While stresses in disks are fairly high, they can be made of smaller ingots and forgings, and inspection is much less ambiguous. While such a machine may be more costly to build, this is one place where relatively little extra money will add greatly to the factor of safety in the bigger, faster machines demanded by an expanding industrial civilization.

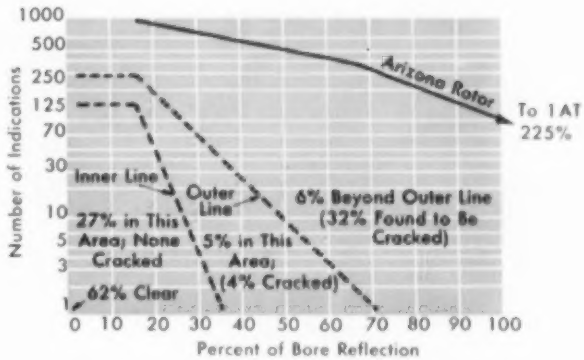


Fig. 9 – Distribution of Total Ultrasonic Indications Versus Their Size in 1500 Rotor Forgings Varying in Weight From 10 to 75 Tons Indicates Safe, Doubtful, and Probably Unacceptable Quality

Conclusion

In conclusion, the Editor would like to place on record his warm approval of the electrical and heavy forging industries for the large amount of important information published at this meeting. In his experience, a bad accident is too often the signal for a large cover-up; if anything is learned about the cause and how to avoid others, such information leaks out slowly if at all. It would have been easy, in these four instances, for the electric utilities and manufacturing industries to have voted lack of confidence in the steelmakers, and vice versa – thus getting exactly nowhere. It is to the credit of all that this situation has been avoided.

Much has been learned from these accidents. Much is yet to be learned about manufacture and design of heavy rotors. An intelligent search is under way by the interested parties.

This is the way it ought to be.

Service Failures of Aluminum Die-Casting Dies

By G. A. ROBERTS and A. H. GROBE*

The three most common types of failures of aluminum die-casting dies are heat checking, pitting and impingement soldering. Heat checking and one kind of pitting are caused by the combined effects of stress and oxidation. A second type of pitting results from breaking of the semi-protective oxide film and subsequent reoxidation. Impingement soldering is actually a mechanical entrapment of aluminum in surface flaws. (S 21, E 13, TS)

Die-casting dies for aluminum represent one of the largest single uses of toolsteels for hot work and require an alloy that will maintain its dimensions in service; resist scaling, pitting, heat checking and the erosive action of molten aluminum; and still be low enough in alloy content to permit reasonable cost. About 20 years ago Vanadium-Alloys Steel Co. introduced the 5% chromium steel which with minor modification is the basic type used almost exclusively today.†

Naturally, over the years the composition has changed. Tungsten additions of up to 5%, vanadium up to 1%, and minor alterations in molybdenum, silicon, and chromium content have been thoroughly field tested. As a result there are at least four commercial variations:

*Dr. Roberts is vice-president, Vanadium-Alloys Steel Co., Latrobe, Pa. Dr. Grobe, formerly director of research for Vanadium-Alloys, is now with Thompson Products, Inc., Cleveland.

†Sold under the trade name Hotform. The original heat had the following composition: carbon 0.28, silicon 1.27, chromium 4.77, tungsten 1.01, molybdenum 1.50%.

Fig. 1 – Large Heat Checks in Aluminum Die-Casting Die

Fig. 2 – The Start of a Heat Check or Narrow Pit in a Die. 2% Nital etch, 500 ×

	H-11	H-12	H-13	H-14
Carbon	0.35	0.35	0.35	0.40
Chromium	5.00	5.00	5.00	5.00
Tungsten	–	1.50	–	5.00
Molybdenum	1.50	1.50	1.50	–
Vanadium	–	0.50*	1.00	–

All, however, are subject to the same kinds of failure in service and there is no clear-cut difference in performance between the principal types H-11, H-12 and H-13. The H-12 steel with 1.5% tungsten and H-14 with 5% tungsten are said to be more susceptible to cracking from sudden temperature changes so water cooling should be used continuously. But H-12 is used with great success for the application. The susceptibility evidently requires somewhat more tungsten to make itself seriously felt. Hot hardness is improved by adding ½% vanadium to H-11 and H-12 and 1% vanadium to H-13, yet the performance difference between H-12 and H-13 is not apparent – perhaps because the hot hardness increase is only evident at temperatures above which dies actually operate.

The three major recognized types of failures of aluminum die-casting dies with long production records are heat checking, pitting and impingement soldering. On some dies, they appear after only a few thousand castings. In fact, heat checking is a common failure not only for hot work toolsteels but for many other high-temperature materials.

Gross cracking of dies is another not too common, but catastrophic, failure. It usually happens very early in the expected die life and is related to poor heat treatment or incorrect die design rather than to service conditions.

In order to determine the mechanism of these three kinds of failure, a number of dies have been studied extensively. The die shown in Fig. 1 is a good example of heat checking, quite obvious because the checks filled with aluminum are in marked contrast to the oxidized steel background. This is a core 6 in. in diameter and 37 in. long, of which only 7¾ in. was in contact with molten aluminum at 1170° F. Over 350,000 castings were produced with this core at a rate of 56 per hr. Its average temperature in service was about 450 to 500° F.

Micro-examination of cross sections through the heat checks and through some pits not apparent in Fig. 1 indicates that the two types of defect are due to stress-corrosion and differ only in size. The alternating stress is due to a combination of thermal and mechanical stresses. These combined with the oxidizing attack of the

*Maximum

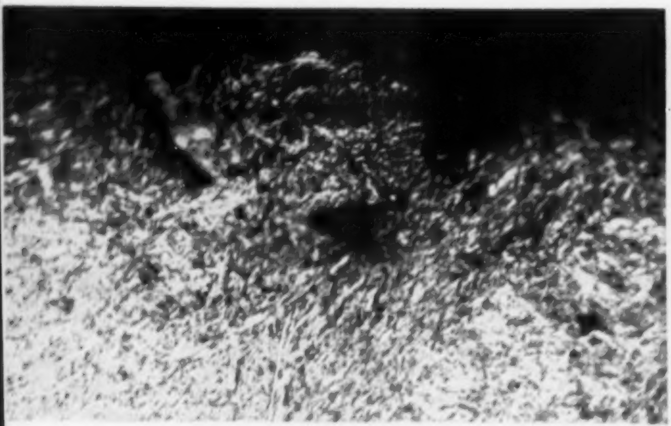


Fig. 3 — Grain Almost Completely Separated from Matrix by Cracking Along Grain Boundaries. 2% Nital etch, 500 ×

Fig. 4 — Crack in Base of Heat Check That Causes Stress Concentration. 2% Nital etch, 500 ×

air cause cracks to form at grain boundaries. The cracks continue to grow until a whole grain or several grains are completely cracked out. If round or oval holes are formed when the grains come out, then the defect is called a pit. If the grains come out along a line then the defects are called heat checks. In any event, when pits are formed they will probably line up and crack between the pits to form heat checks. The beginning of such a heat check or pit is shown in Fig. 2.

The growth of a defect is illustrated more clearly in Fig. 3 and 4. The grain shown in Fig. 3 is almost completely separated from the matrix by cracking along grain boundaries. After it falls out, the small crack at the base of the cavity (Fig. 4) causes stress concentration that will accelerate the growth of the pit or heat check.

Almost all of the heat checks in this die were filled with aluminum but in the metallographic examination there was no evidence of the aluminum attacking, alloying with, or dissolving the die steel. In every instance there was an oxide film or an air gap which prevented direct contact between the aluminum and die steel as shown in Fig. 5.

The core insert die shown in Fig. 6 is a good example of impingement soldering and pitting. With it, 25,000 castings were produced at a rate of 125 per hour. The temperature of the molten aluminum was 1200° F. and the die was maintained at 300 to 400° F.

In order to study the impingement soldering a small flat was ground at a very slight angle to the surface which provided a larger area for examination. It was found that the aluminum was not welded to the die steel but is held mechanically by very small pits or scratches. After this nucleus is formed, the aluminum deposit builds up readily. One of the areas examined is shown in Fig. 7; the light patches are aluminum embedded in small pits, the dark ones are scale.

The pits on this die differ in appearance from heat checks described earlier and appear to have resulted from scratching or breaking of the semi-protective oxide surface that is built up on a die when it is broken in. When the scale is broken, the steel reoxidizes and if the cycle is repeated several times, a broad, shallow pit develops. Because of the unusually heavy pitting of this die, it is suspected that the die rusted between heat treatment and installation in service and the rust prevented the formation of a protective oxide surface.

As a result of this investigation, certain facts are apparent regarding manufacture of dies for this service:

1. The surface should be as free of scratches as possible.

2. Stamp marks or other sharp stress-raisers should be avoided.

3. A tight, adherent, uniform oxide film should be maintained on the die as long as possible. A proper "break-in period" in which an oxide film is purposely built up is very important.

4. Scratching oxide films to expose bare die metal should be avoided.

Fig. 5 – Aluminum Trapped in Heat Check, Separated From Steel by Scale. 2% Nital etch, 500 ×

Fig. 6 – Top and Side Views of Core Insert Die Which Illustrate Pitting and Impingement Soldering

Many metallurgical considerations involving steel properties and heat treatment were also a byproduct of the study. Proper treating techniques involve these "dos and don'ts":

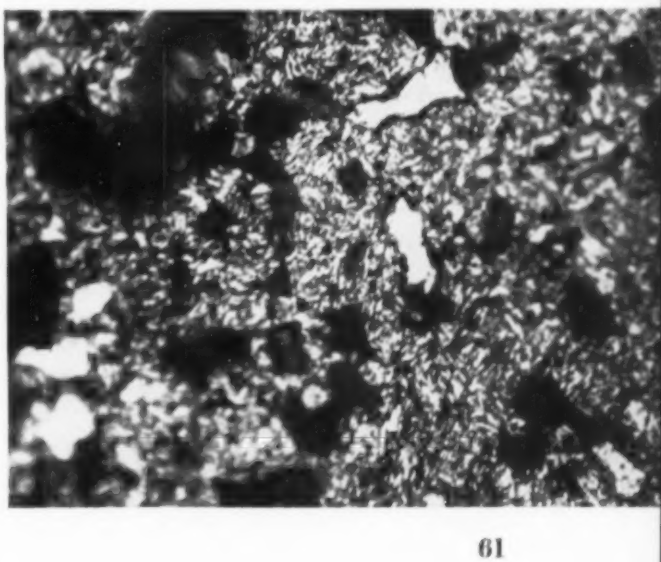
1. Avoid decarburization; even a little is dangerous. Ideal treating techniques involve pack hardening in "spent pitch coke" or carefully controlled atmosphere with the surface plated to impede carbon migration in or out.

2. Slight carburization is not as objectionable as decarburization and might even be helpful. Uncontrolled carburization is objectionable. (Recent reports of improved service life with intentionally carburized dies are known to be subject to design and size considerations. Grain-boundary carbide precipitate is to be avoided to prevent rapid spread of heat checks.)

3. Cool fast enough in hardening to avoid knee products (pearlite or spheroidite formation). The steel is air hardening but poor circulation of air on heavy dies may cause a small amount of transformation on cooling.

Several new steels have been developed for aluminum die-casting dies whose compositions were adjusted to provide improved resistance to oxidation, resistance to wear and scratching, more uniform response to heat treatment, and more uniform microstructure. Unfortunately not all these improvements can be accomplished with one analysis but field tests on dies made from the new compositions indicate that service life has been improved.

Fig. 7 – Aluminum Mechanically Embedded in Pits Causes Impingement Soldering Failures. 2% Nital etch, 500 ×



Epoxy Coating

If there is one type of furniture that really has to stand up under all kinds of abuse, it is that used in laboratories. Not only does it get knocked about much more than do chairs and tables in an office, but it is also subject to all sorts of chemicals which can spoil a good-looking finish. Unfortunately we can't predict what will be spilled on the furniture so we have to standardize on coatings that not only are resistant to practically everything but must also be reasonably priced and easy to apply.

Resistance to chemical attack is the primary consideration and we have adopted a standard series of tests to evaluate all possible coating material offered to us. For each test, sample steel panels 2 × 3 ft. are processed according to the coating manufacturer's instructions and then exposed to the chemicals found most frequently in industrial, pharmaceutical and hospital laboratories. The most severe of these tests is shown in the table. The time required for any change in color or appearance, softening or break-through is used for evaluation.

To date, the only coatings that satisfactorily pass all our requirements are those formulated with Epon resins, the epoxy polymers manufactured by Shell Chemical Corp. Fortunately these coatings also have excellent resistance to scuffing and impact and don't crack or spall even when severely dented. We have standardized on these coatings for our conveyerized finishing line in the manufacture of all steel and aluminum components.

The step-by-step operations, illustrated in the photographs on the following two pages, are as follows:

Before application of the epoxy coating, laboratory furniture components are conveyed through a degreaser where sprays of hot phosphate cleaner are followed by a water rinse and a flash drying oven at 325° F. to remove traces of oil, dust, dirt and fingermarks, leaving a crystalline protective coating on the metal before the first coat of finish is applied.

The first coating to be applied is a flash primer which masks slight scuff marks, water spots or other visual imperfections. Spray booths are located 30 ft. apart to allow the primer-coated part, traveling at 4 ft. per min., to dry thoroughly before the second and third coats are applied.

Safeguards Laboratory Furniture

By WILLIAM A. POE

Vice-President in Charge of Manufacturing
Brown-Morse Co., Muskegon, Mich.

Primer and finish coats are applied manually using a spray gun pressure of 50 psi. to insure that the coating thickness will exceed 0.002 in. after curing.

The finish is baked for 17 min. at 375° F. in a gas-fired tunnel oven. The components are allowed to cool on the conveyer for 1 hr. before assembly.

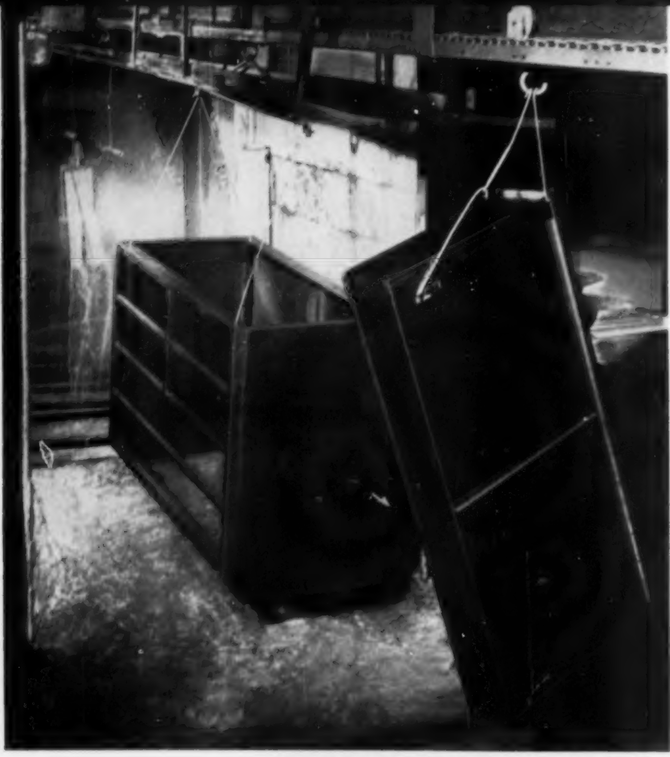
The tops are then attached, and after final inspection the cabinets are ready for the deluge of spilled reagents that awaits them in laboratory service.

Test Used to Evaluate Coatings for Laboratory Furniture

PART 1 – Subject panel to the reagents listed below, and check results after 1 hr., and again after 24 hr. or at breakdown:

30% Nitric acid	20% Ammonium hydroxide	Chloroform
70% Nitric acid	10% Ammonium hydroxide	Xylol
37% Hydrochloric acid	Saturated sodium hydroxide	Toluol
48% Hydrochloric acid	Saturated sodium sulphide	Ethyl alcohol
33% Sulphuric acid	Saturated zinc chloride	Methyl alcohol
77% Sulphuric acid	Saturated calcium hydrochloride	Formaldehyde
Glacial acetic acid	Acetone	Hydrogen peroxide
85% Phosphoric acid	Ethyl acetate	Gasoline
60% Chromic acid	Ethyl ether	Nail polish remover (commercial)
90% Formic acid	Carbon tetrachloride	Naphtha
Aqua regia	Phenol	Lacquer thinner
40% Ammonium hydroxide	Furfural	Acetic anhydride

PART 2 – Subject panel to continuous reflected heat up to 750° F. or in an overturned bunsen burner flame for 1 min.

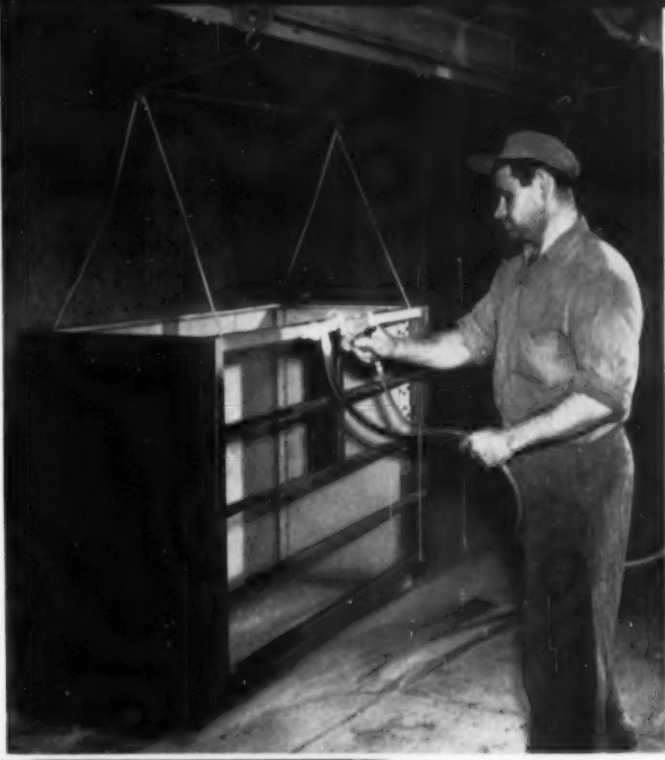


Furniture Components Starting Their Trip Through the Degreaser

The First Coating to Be Applied Is a Flash Primer

Spray Booths Are Spaced to Allow for Drying Between Coats

Primer and Finish Coats Are Applied Manually by Spray Gun



Components Cool on the Conveyer After Baking

When Tops Are Attached Cabinets Are Ready for the Final Inspection

Electrolytic Polishing of Nodular Cast Iron

*By R. E. SKODA**

Electropolishing of nodular cast iron in a solution of CrO_3, acetic acid and water is a rapid and easy method of preparing specimens for metallographic examination. (M 21, CI)

THE SHAPE of the graphite particles in cast iron greatly influences the properties of the casting. When the graphite is present as tiny balls or spherulites instead of as flakes in gray iron, the machinability, wear resistance, impact strength and other mechanical properties of the casting are improved considerably. Spherulitic graphite particles form during solidification when a small amount of magnesium or cerium has been added to the molten iron just before casting.

Studies of nodular cast iron thus treated require close observation of the microstructure of the metal and the included graphite. Unfortunately, in mechanical polishing this kind of specimen, it is difficult and sometimes tedious to retain the graphite and reveal its true structure. In this laboratory an electrolytic method has been developed for preparing cast iron specimens for metallographic examination. Cast irons containing up to 3.3% C and 3.4% alloying elements have been satisfactorily prepared in less than 5 min.

The sample is rough ground through No. 600 silicon carbide paper disks and then electropolished in an electrolyte consisting of 133 ml. of glacial acetic acid, 25 g. of CrO_3 and 7 ml. of water (as described by C. E. Morris in *Metal Progress* for November 1949, p. 696). The solution is prepared by dissolving the CrO_3 in the acid and then adding the water. Electropolishing is performed under the following conditions:

Voltage	50 v.
Temperature	68 to 78° F.
Current density	0.022 to 0.026 amp. per sq.mm.
Time	About 30 sec.

Violent agitation is necessary for satisfactory results and to obtain it we use the commercially available Disa electropolishing machine distributed by the Uddeholm Co. of America. The solution should be changed frequently since it deteriorates rapidly with use.

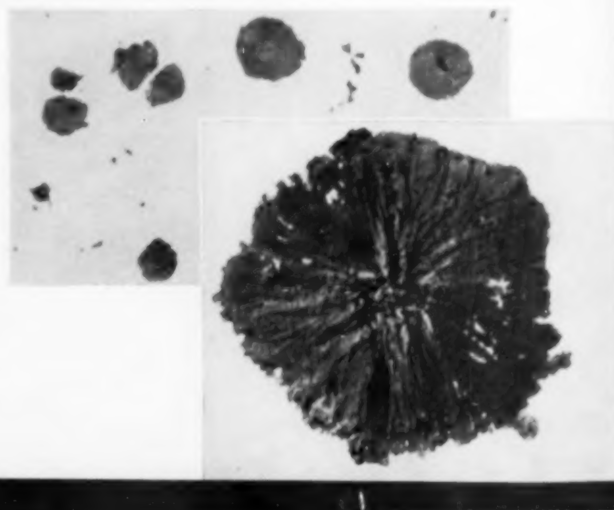
After electropolishing, the specimen is somewhat stained and is lightly etched. The graphite particles, though not disturbed during the electrolytic polishing step, are left protruding above the surface like tree stumps. Apparently the iron matrix is preferentially attacked during electrolytic polishing.

For the final mechanical polishing operation, we use Microcloth (Buehler Co.) and No. 87724 Precisionite (Precision Scientific Co., 0.1 micron particle size) with large amounts of liquid green soap as a vehicle. The specimen is held against the cloth with light pressure for only a few turns of the wheel. This brings the graphite to the level of the matrix and removes the stains and etch figures.

An example of work done by this method is given in the micrographs below.

*Alloy Studies Research, General Electric Research Laboratory, Schenectady, N. Y. The author wishes to acknowledge the help of members of the metallographic laboratory, especially J. B. Newkirk, during the development of this technique.

Graphite Spherulites in Electropolished Cast Iron. Unetched; 100 × and 500 ×



The "Flash" in Flash Welding Can Hide Many Defects Unless Rigidly Controlled

Flash Welding Jet Engine Rings

*By ARTHUR G. PORTZ**

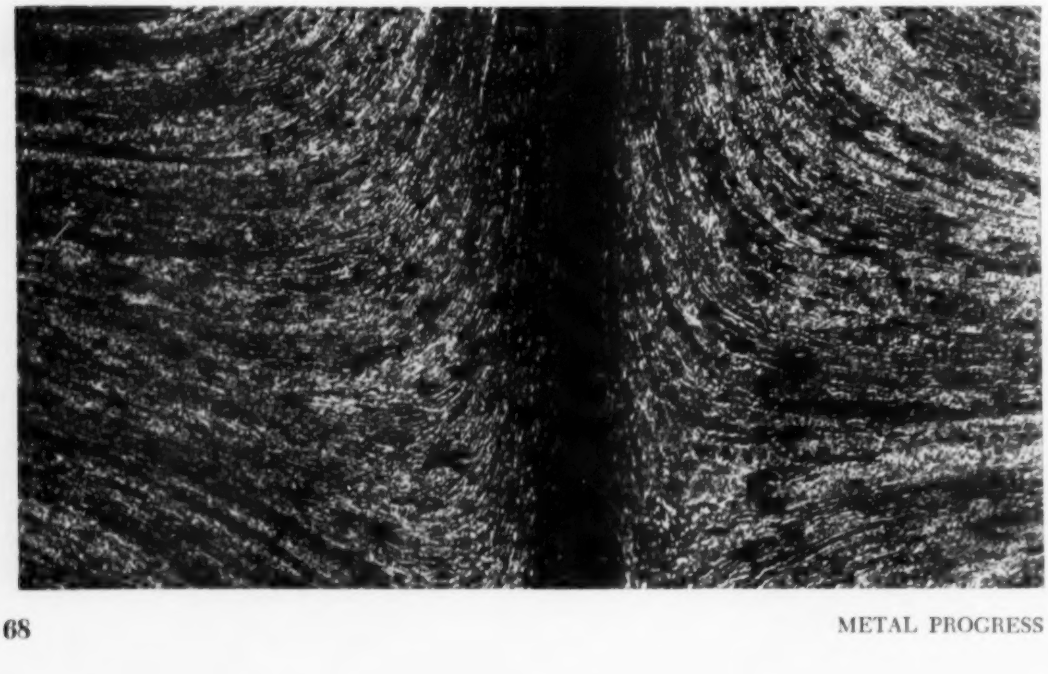
Flash welded rings have replaced forgings and castings in jet engine applications because of the savings in machining that are realized. To maintain the welding quality required, eight different variables must be predetermined and controlled. (K 3)

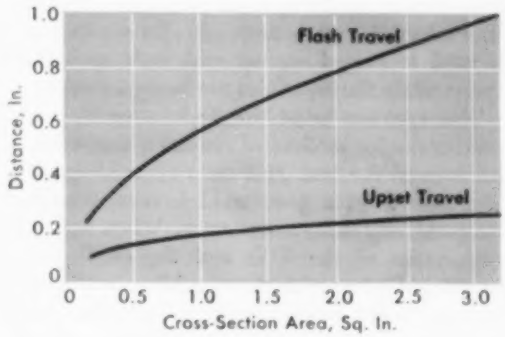
FLASH WELDING is one of the oldest electrical welding techniques. Its principal advantages, absence of filler rod and high productivity, have long been recognized but only with the aid of metallurgical quality control has it become established as a reliable and efficient means of joining metals. Flash welded rings have replaced forged and cast rings in jet engines with considerable savings in machining cost and no sacrifice in quality. Such alloys as Inconel "X", Timken 16-25-6, titanium alloys and the stainless steels are being used in the manufacture of such rings.

*Chief Metallurgist, Cleveland Welding Div., American Machine & Foundry Co., New York.

Cold Stretching Not Only Sizes the Ring but Also Proof-Stresses the Weld

Good Weld in Ti-150 A Is Produced by Increasing Upset Pressure and Decreasing Flash and Upset Time. Nitric-hydrofluoric acid etch, 100 ×





Flash and Upset Travel Distance as a Function of the Cross-Section Area. Values apply only where ratio of maximum to minimum dimension does not exceed 1.5

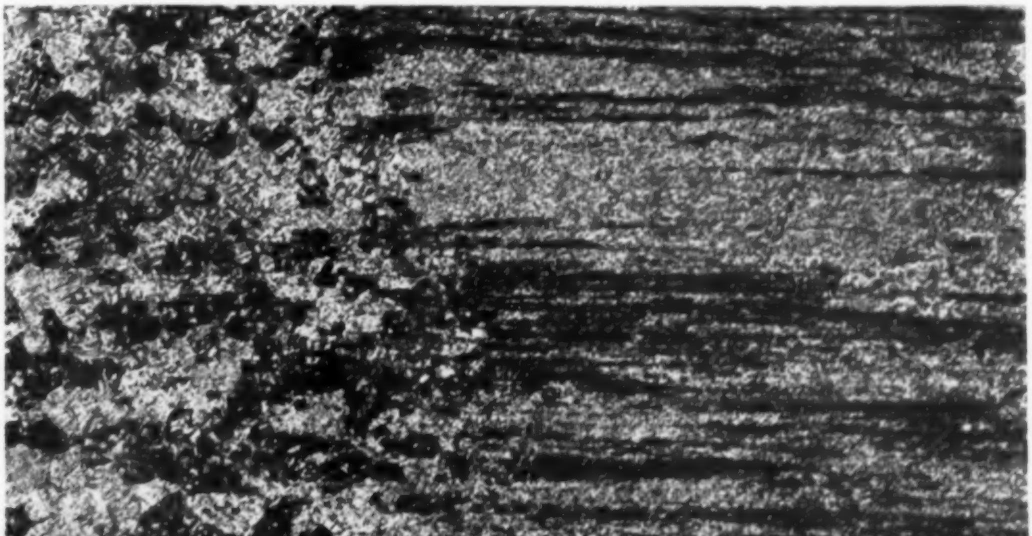
The Small Flash of the Upper Sample Indicates That Current, Upset Travel and Pressure Are Too Low for Satisfactory Welding. The flash of the lower sample indicates good welding practice

In the process a flash-butt weld is made by passing enough current between two pieces in very light contact with each other to cause melting of the surfaces. When the two surfaces are hot the parts are forced together with sufficient pressure to squeeze out most of the molten metal, containing any slag or oxide that may have formed, and to forge weld the plastic surfaces below. After the flash is chipped or machined off, there is no external indication of the weld.

The Cleveland Welding Co. started welding circular products in 1911 and has progressed from iron tire rims for horseless carriages to the complex alloy rings used in jet engines. The transition occurred effortlessly when a forge shop asked us to weld some rings of a special material. After two years of increasing demand for this product, we were offered a contract to make rings for the J-65, axial-flow, turbojet engine. We hesitated until we learned that the rings we had been making were then in use in jet aircraft.

The older rings were forging blanks which required considerable hot work after welding, but the present rings are made from rolled or extruded shapes and the only work performed between welding and finishing is a sizing stretch (cold). The amount of machining necessary is

Unsatisfactory Flash Weld in Ti-150 A Has "Cast" Structure With no Ductility. Nitric-hydrofluoric etch, 100 ×



reduced appreciably by using rolled or extruded sections of approximately the same shape and slightly larger than the final contour required. In addition, flash welded rings can be held to closer out-of-round and out-of-flat tolerances than forgings or castings, which also contributes to the reduction in machining costs. Quality is controlled by rigid inspection of the raw material and by strict maintenance of the specific welding schedules established for each alloy in each size and shape used.

There are eight variables for each welding schedule. Three of these, the initial die opening and the distances the parts move during flashing and upsetting, are governed by the cross section of the piece and are selected from a series of charts based on previous experience. The other five, voltage, upsetting pressure, flashing time, upsetting time and clamp-holding time, must be determined for each new job. An oscillograph is used to record current and flash and upset cycles while the schedules are being established.

The appearance of the flash, once the only nondestructive method of checking the weld, is still one of the best indicators of weld quality. The flash from a good weld is crack-free and comparatively steep and narrow. When both the appearance of the flash and the oscillograph record indicate satisfactory welding conditions, six test welds are made from straight bars of the same cross section as the rings. One is used for metallographic inspection and the rest are cut into tensile specimens. If the strength of the weld is more than 95% of the strength of the base metal and the ductility is satisfactory, the welding schedule is used to prepare two pre-

Nondestructive Case Depth Measurements

*By ROBERT H. McCREERY**

Depth of case is controlled in production by measuring the Rockwell hardness of the surface and comparing it to predetermined limits specified on a series of control charts. (J 28, S 18)

PERFECT control of case hardening is not possible in most production heat treating departments because the only accurate means of measuring case depth destroys the test piece. The usual procedure is to select samples from each batch, or periodically from continuous furnaces, and measure the depth either visually or by hardness checks on a cross section through the critical areas. Although it is possible to obtain extremely accurate measurements on the test sample, these methods will not indicate if another piece in the same batch is defective, as, for example, when an off-analysis steel is processed.

Several years ago we developed a simple nondestructive control system that allows the furnace operators to make case depth checks without continual laboratory supervision. It requires only Rockwell hardness measurements and comparison of the values obtained with a control curve established for the steel and heat treatment involved. Process control has been very satisfactory; not only has it minimized defective parts but it also

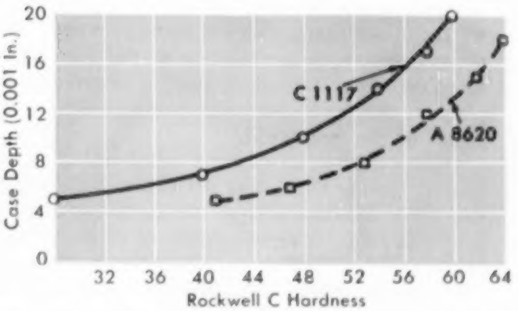
*Metallurgist, Warner Gear Div., Borg-Warner Corp., Muncie, Ind.

production rings for testing. These are welded, sized, X-rayed and tensile tested. If they are satisfactory production is authorized.

Cut-to-length stock is roll-formed and bumped in a press to make a flat-top circle with ends in a straight line. The weld is made and while still hot, the flash is chipped off. With complex cross sections the flash is removed with a deburring machine. The ring is then annealed, flattened and expanded cold. All jet engine rings are stretched a minimum of 1% of the circumference; small rings may be stretched as much as 3%. This stretching not only makes the rings round and true but also gives the weld a proof stress. Rings made from Timken 16-25-6 require a stretch of 7 to 10% to meet the strength requirements usually obtained by hot-cold working.

When we made the first rings of titanium alloy Ti-150 A, we used about 50 test bars before we produced a satisfactory weld. The first welds were weak and brittle (tensile strength about 65,000 psi. and no ductility) and micrographs of the weld showed cast grain structure in a band about 0.05 in. wide. By increasing the upsetting pressure to about three times that used with stainless steel and reducing both flashing and upset time, this structure was eliminated and satisfactory welds were produced.

Cast structure is referred to in many specifications but so far I have seen it only in titanium. Stainless steel welds sometimes show a dark line about 0.005 in. wide when etched but its structure does not appear "cast" even at 1000 ×. Tensile tests of such welds indicate the same strength and ductility as the base metal, and in service this structure is entirely satisfactory.



Increase in Surface Hardness as a Function of Case Depth for Two Steels Carbo-Nitrided at 1550° F.

has served as a trouble-shooting guide to the operator to signal when some variable is out of control. The procedure is based on the fact that the Rockwell hardness number measures the depth of the major load indentation less the minor load indentation and is affected by both surface hardness and the hardness of the area immediately below that surface. For example, if the indentation is 0.003 in. deep, the reading has been affected by at least 0.030 in. of the material immediately below the indentation. Thus an increase in case depth increases the values obtained in surface hardness measurements. If a microscopic measurement of various case depths is correlated with the appropriate Rockwell scale reading, a curve of case depth as a function of hardness can be plotted for each steel, section, quench and process. Most production case hardened parts involve only a few steels or processes and once the curves have been established they provide a reasonably accurate means of checking all production parts. Some typical curves are shown in the chart.

The indentation-affected zone varies with the Rockwell scale used. With heavier loads the penetration and indentation-affected zone are deeper. The regions of accurate testing will thus vary with the Rockwell scale used. We have found that the "15 N" scale is most appropriate for case depths of 0.001 to 0.005 in., the "A" scale for depths of 0.005 to 0.010 in. and the "C" scale for depths of 0.010 to 0.020 in.

Some of the variables that influence the hardness readings are the hardenability of the steel, section size, the hardening medium and quenching speed, which may differ between furnaces. It may be necessary to set up separate control charts for each combination of these variables.

Occasionally hardness readings will be outside the specified limits yet the case depth is found to be correct. When this happens the furnace operator checks the hardness tester, the quenching conditions, the furnace atmosphere and the composition of the steel and can usually locate and correct the difficulty before very much material is improperly processed.

Things the World Should Know*

I CHOOSE tonight to speak of the dangers intrinsic to man's possession of nuclear power. I would prefer the most pleasant topic now called "Atoms for Peace". But the essential condition for the peaceful use of the atom is — peace. And peace has not yet been achieved. All along the lengthy and tortuous path to peace, nations will constantly meet the temptation to war.

The United States has done one important thing to deter our enemies from yielding to this temptation. We have built up an arsenal of atomic weapons.

However, our quest for security had led us to a strange land. We are no longer secure about the one thing that always in the past was secure — that there would be a mankind living here on earth until man's temporal history would be terminated by an act of Almighty God. Man now has the power to put an end to his own history.

The new danger lies in the fact that we do not understand the danger inherent in the release of nuclear energy. And when I say "we" I mean "we, the people". An essential insurance against the dangers inherent in nuclear weapons is an America-wide public and a world-wide public that fully realizes the cosmic dimensions of this danger.

Before the thermonuclear tests at our Pacific Proving Ground in 1954 took place, a policy of almost utter silence had been established. However, 27 Japanese fishermen announced to the world the first fateful news about the lurking catastrophe that may possibly lie in wait for all of us. In this instance, the official policy of secrecy proved inept. When the secret came out, through the wrong channels, the shock to world opinion rivaled, in its own way, the blast of the H-bomb itself.

This thermonuclear explosion shattered all previous concepts of that central element of warfare which is called "power". It crosses the threshold into a separate category of power by the sheer force and reach of its blast. It also releases dangerous radioactive atmospheric contamination so serious that it could be catastrophic. A sufficiently large number of such explosions would render the earth uninhabitable to man. This is plain fact.

One of the products is radioactive strontium which continues to reach the earth for years, and thence passes into food and is absorbed into the bone structure. There is a limit that can be absorbed without harmful effects. The problem has been to fix the limit. A year ago the public was informed that the radiostrontium now in the soil would have to increase 1,000,000 times before increased frequency of bone tumors could be recognized. Recent statements have revised that figure drastically and significantly downward from 1,000,000 to 10,000. In any event, there is a limit. Consequently, there is a limit to the number of large thermonuclear explosions that the human race can withstand without harmful bodily effects. This is a crucial point to remember when there is talk of an all-out nuclear war.

In view of the new dimension of destructiveness that large thermonuclear bombs create, in view of the fact that their effects persist for years after their use against an enemy, what are the limits to their use in a large-scale war? On whom should we depend for such decisions? Are not we, the people, involved right up to the hilt of our common safety? Indeed we are.

Public understanding cannot be created unless we revise our past policies of secrecy. What I propose, therefore, is a "Meeting at the Summit"—this time at the "Atomic Summit"—in order to explain to the world American power, which is the power of the free world.

I propose that we convene this meeting at our Pacific Proving Ground at the island of Eniwetok, and there detonate a large thermonuclear weapon before an audience representative of *all* the peoples of the world.

The group present ought to include men who participate in the making of public policy in all nations. They would, I should hope, later meet to talk together about war and peace, and about one essential condition of both; that is, the control of nuclear energy. They would come away from this experience utterly convinced, as I was, that humanity has entered a new age, in which certain old ideas about peace and war have become obsolete, useless and even dangerous.

In addition, at the meeting there would also be the press, who would be prepared to give the peoples of the world a fresh vision of the new kind of power that frail man now wields.

The purpose would not be to strike terror into the hearts of men, but to implant understanding in their minds. The purpose would be to arouse all the forces of the human imagination, reason and will. They are mightier than the physical forces of the atom. They are the spiritual forces upon whose vigor we set our hopes for a just and durable peace.

*Verbatim excerpts from address by Thomas E. Murray, member of U.S. Atomic Energy Commission, before Fordham Law School, New York City. Commissioner Murray was speaking as a private citizen, since the U.S. Atomic Energy Commission "by formal action rejected his motion to invite foreign observers to witness tests of nuclear weapons".

Corrosion Resistance and Mechanical Properties of Cr-Ni-Mn Stainless Steels

*By R. A. LULA and W. G. RENSHAW**

The corrosion resistance and mechanical properties of the new A.I.S.I. Types 201 and 202 are excellent for many structural applications in corrosive environments. A modified alloy with more chromium and nickel may be necessary to resist the more severe applications in the chemical industry. (SS)

In the past many attempts have been made to produce commercial chromium-manganese austenitic steels, especially during nickel shortages, but none of these compositions has outlived these emergencies to become accepted as a standard grade. The main factor which heretofore has prevented the large-scale commercial development of an austenitic chromium-manganese steel is that chromium must be limited to 15% in order to hot roll large ingots successfully. With higher chromium contents, delta ferrite is present at hot rolling temperatures and causes difficulty.

With only 15% chromium and without the beneficial influence of nickel, the corrosion properties of such alloys are suitable only for mild conditions. For more corrosive conditions it is necessary to raise the chromium content to improve the corrosion resistance. There are two methods by which this may be done – use a high nitrogen content, or add some nickel.

Nitrogen is strongly austenitizing and the amount of nitrogen which can be taken into solution is high since both chromium and manganese increase the solubility. With steels unusually high in nitrogen (0.30 to 0.70%) the chromium content can be raised to 17% without nickel additions and a completely austenitic structure is maintained up to 2300° F. The strength of these steels is higher than that of the conventional chromium-nickel grades and the high-temperature properties look promising. Due to the absence of nickel, the corrosion properties are inferior to the chromium-nickel steels. These high-nitrogen, chromium-manganese steels might eventually develop as a group in their own right for structural and high-temperature applications but their corrosion and mechanical properties preclude placement of these steels in the same category with chromium-nickel grades.

Raising the chromium content by use of nickel additions has given far better results. Both the corrosion and the mechanical properties of these steels are very similar to those of the chromium-nickel grades. The increased nickel content not only makes a direct contribution to the corrosion resistance but also permits a higher chromium content while simultaneously allowing a reduction of the manganese to less than 10%. All these enhance the corrosion resistance.

The chromium-nickel-manganese grades not

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Composition of Chromium-Nickel-Manganese Stainless Steels

A.I.S.I. Type	Designation	C	Mn	Cr	Ni	N
201	17-4-6	0.15 max.	5.50— 7.50	16.0—18.0	3.50—5.50	0.25 max.
202	18-5-8	0.15 max.	7.50—10.00	17.0—19.0	4.00—6.00	0.25 max.
—	204	0.10 max.	7.50—10.00	17.0—19.0	4.00—6.00	0.25 max.
—	204 L	0.06 max.	7.50—10.00	17.0—19.0	4.00—6.00	0.25 max.
—	20-6-8*	0.10 max.	7.00— 9.00	19.0—21.0	5.00—7.00	0.20—0.35

*Experimental

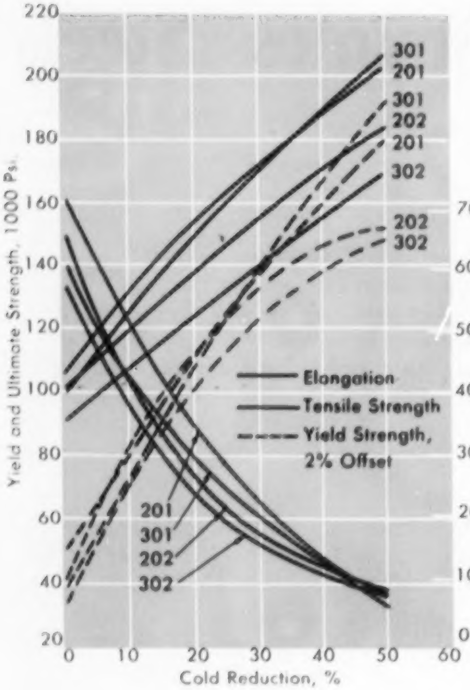


Fig. 1 – Effect of Cold Working on the Mechanical Properties of Cr-Ni and Cr-Ni-Mn Steels

only fill a vital place with the present shortage of nickel, but also promise to grow in importance in the future since the rate of increase in nickel production is exceeded by the rate of increase in the production of nickel-bearing alloys.

The development of such steels is by no means new. The Allegheny Ludlum Steel Corp. has made them for more than 20 years. Renewed interest in the past several years, however, has led to a comprehensive evaluation of these steels and the designation of two new A.I.S.I. grades, Types 201 and 202. There are also two lower carbon compositions which are arbitrarily designated as 204 and 204 L, following the procedure for the 300 series, even though the lower carbon alloys are not yet standard A.I.S.I. grades. Another experimental grade with higher chromium content has been designated 20-6-8. The corrosion and mechanical properties of these chromium-nickel-manganese steels are very

Fig. 2 – Magnetic Permeability of Cold Worked Stainless Steel

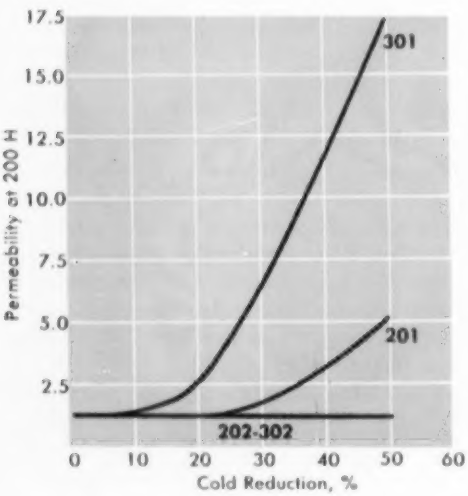
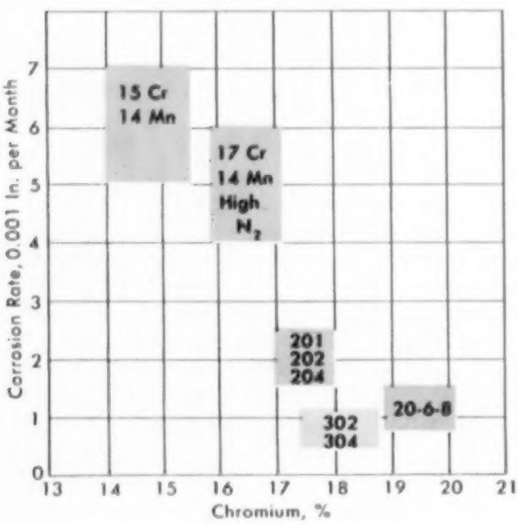


Fig. 3 – Effect of Chromium Content on Corrosion Rate in 65% Nitric Acid



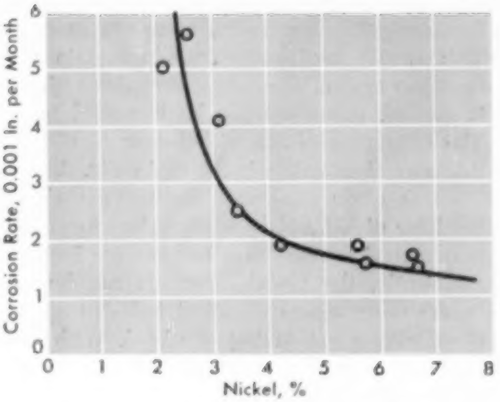


Fig. 4 – Effect of Nickel Content on Corrosion of 17-10 Cr-Mn Steels in 65% Nitric Acid

similar to those of the standard chromium-nickel grades but in addition they have some properties that make them more desirable for many commercial applications. Their compositions are shown in the table on the opposite page.

In Type 201, which has the lowest chromium content, 3.50 to 5.50% nickel is sufficient to insure an austenitic structure at hot rolling temperatures. With the increased chromium content in Types 202, 204 and 204 L, the nickel level must be raised to 4.00 to 6.00%. As chromium is increased (Type 20-6-8) a further increase in nickel content to 5.00 to 7.00% is necessary. It should be pointed out, however, that in all these alloys, the austenitizing influence of the nickel and manganese is not adequate and must be supplemented by nitrogen additions.

Type 201, which has the lowest chromium, manganese and nickel content, attains high mechanical strength when cold worked. The strength is caused by both the decomposition of austenite to martensite due to cold work and the strain hardening of the undecomposed austenite. In this respect, Type 201 is similar to Type 301 in the chromium-nickel steels and can be used primarily for structural applications. The other chromium-nickel-manganese alloys are more stable and have a lower rate of hardening by cold work.

The tensile properties of the stainless steels in the annealed and in the cold rolled state, shown in Fig. 1, are an indication of their performance characteristics in structural members and also reflect their general suitability for fabrication. Types 204, 204 L and 20-6-8 are not shown since the mechanical properties are very similar to those of Type 202. Type 201, like Type 301, owes its high tensile strength and increased rate of work hardening to the partial transformation of austenite to martensite as indicated by the increase in magnetic permeability shown in Fig. 2. Type 202 is more stable and behaves like the chromium-nickel grade, Type 302. The elongation of Types 201 and 202 is about the same as that of Types 301 and 302, respectively.

Other mechanical properties, such as impact strength at room and low temperatures, and the fatigue strength of these chromium-nickel-manganese steels, have been found to be equivalent to these properties in the Cr-Ni grades.

The forming characteristics of chromium-nickel-manganese steels are similar to those of the chromium-nickel grades. There is sufficient fabricating experience to show that generally the forming, bending and deep drawing properties are the same and that the change from chromium-nickel to chromium-nickel-manganese steels can usually be made without any alteration of tooling or forming practices.

The chromium-nickel-manganese steels can

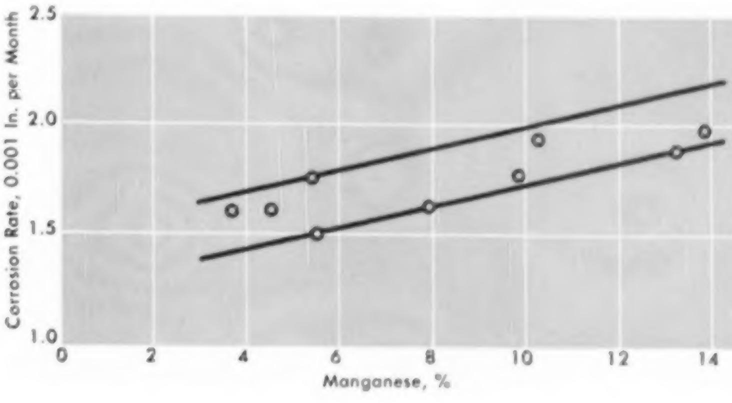


Fig. 5 – Effect of Manganese Content on Corrosion of 17.5% Cr, 4% Ni Steels in 65% Nitric Acid

be welded by all the conventional methods applied to the chromium-nickel steels and the weld properties are excellent when shielded-arc methods, arc welding with coated electrodes or spot welding are used. Filler wire or electrodes have been developed to produce welds of the same composition as the base metal. Conventional Cr-Ni electrodes can also be used.

Corrosion Properties

Of the individual elements, chromium and nickel are the most effective for improving corrosion resistance of stainless steel. The straight chromium-manganese austenitic steels, because of the limitation on chromium content and the absence of nickel, do not resist corrosion as well as chromium-nickel steels. The advantages of chromium-nickel-manganese steels are shown in Fig. 3, which compares corrosion rates in boiling 65% nitric acid with typical values for nickel-free chromium-manganese and also chromium-nickel steels. The chromium-nickel-manganese steels are similar to the chromium-nickel steels, while alloys with less than 17% chromium show three to six times greater attack. The pronounced difference may be due in part to the difference in nickel content and not to variation in chromium content alone, as indicated in Fig. 4. Nitric acid attack decreases sharply as nickel is increased from 2 to 4% in 17% chromium-nickel-manganese steel. Some additional slight improvement is realized by raising nickel to 6%, where rates begin to approach those of chromium-nickel steels.

Manganese has relatively little influence on behavior of chromium-nickel-manganese steels in boiling 65% nitric acid, as shown in Fig. 5. This is not necessarily true in certain other corrosive media. Where best corrosion resistance is needed, chromium can be increased to 20%. The advantage of 5½% nickel over 4% nickel in this chromium range is shown in Fig. 6.

These nitric acid data explain the obvious need for nickel and high chromium to produce best corrosion resistance. If both are increased sufficiently, the Cr-Ni-Mn steels can be used in the more severe chemical industry applications with a net saving of nickel. With intermediate corrosive mediums such as acetic, sulphurous or phosphoric acid the new A.I.S.I. steels behave like the older 18-8 alloys.

Fig. 6 – Effect of Chromium Content on Corrosion in 65% Nitric Acid of Two Heats of Cr-Ni-Mn Steel

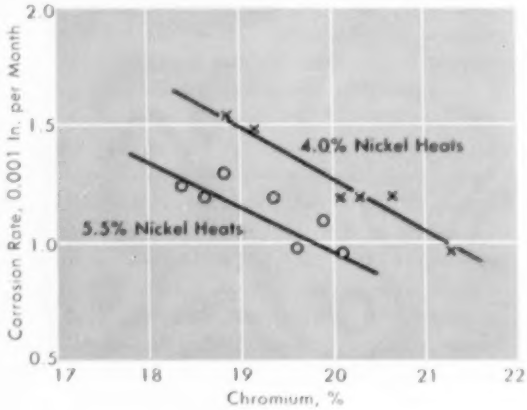


Fig. 7 – Pitting of Panels Exposed to Salt Spray Corrosion Test

17% Cr, 14% Mn, 0.45% N | *Type 204* | *20-6-8* | *18-8 Cr-Ni*

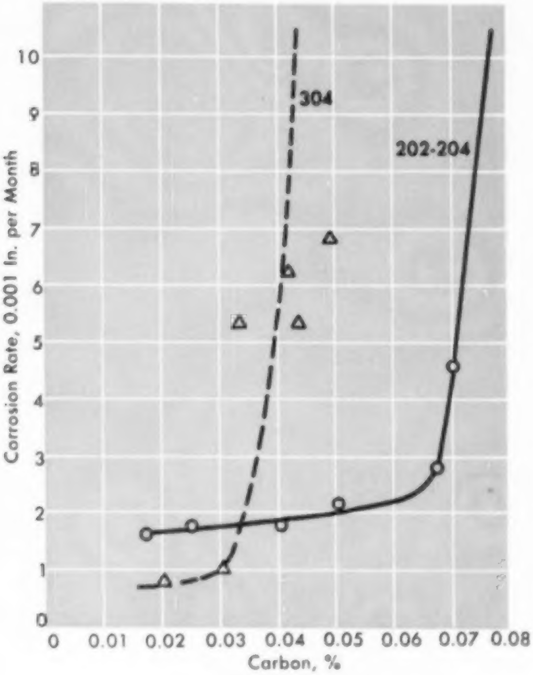


Fig. 8 – Effect of Carbon Content on Corrosion Rates in 65% Nitric Acid After Sensitizing 2 Hr. at 1200° F.

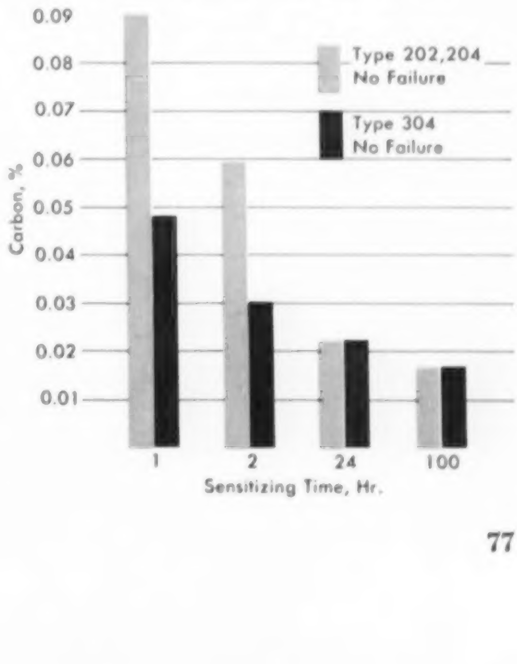
Localized corrosive conditions, which are typified by chloride solutions, present a somewhat different situation. Where manganese exerts relatively little influence on corrosion resistance to nitric acid and intermediate corrosive conditions, it can seriously impair pitting resistance. Nickel, on the other hand, is very beneficial and 5% to 6% Ni appears to impart resistance to salt spray nearly equal to that of chromium-nickel steels, as shown in Fig. 7. All austenitic chromium-nickel-manganese or chromium-manganese steels, such as 18-8, are subject to stress-corrosion cracking, as indicated by boiling magnesium chloride tests.

Where severe corrosion conditions are involved, the problem of intergranular corrosion after welding or stress-relieving can be critical. Like chromium-nickel steels, the chromium-nickel-manganese steels can be made immune to intergranular attack by lowering carbon content. The maximum carbon content for this purpose in chromium-nickel-manganese steels is higher than that in chromium-nickel steels. Figure 8 shows a comparison of these two steels with varying carbon contents in boiling nitric acid after sensitizing 2 hr. at 1200° F. While 304 is immune to intergranular attack only up to 0.030% C, as indicated by the rapid increase in corrosion rates above this point, 202 and 204 resist sensitization with up to 0.065% C. This points to an important advantage of these steels, further demonstrated by the results of copper sulphate tests on material heated up to 100 hr. at 1200° F., as shown in Fig. 9. With short sensitizing times, the advantage of chromium-nickel-manganese steels is evident. After long heating for 24 hr. or 100 hr., they behave the same as chromium-nickel steels.

In resume, the corrosion resistance of chromium-nickel-manganese steels is superior to that of chromium-manganese steels with little or no nickel. Types 201 and 202 possess adequate corrosion resistance in atmospheric environments or in many corrosive mediums where Types 301 and 302 are now used. When severe conditions must be met, such as in chemical industry applications where Type 304 is now employed, the experimental steel 20-6-8 appears to be satisfactory. This alloy has better resistance to localized attack than Type 201, 202 or nickel-free chromium-manganese steels.

With short-time sensitizing, the chromium-nickel-manganese steels are less susceptible to intergranular corrosion than Type 304 of equal carbon content, and a 204 L type corresponding to Type 304 L chromium-nickel steel would not require a maximum carbon content as low as 0.03%.

Fig. 9 – Comparison of Types 202 and 204 With Type 304 in Copper Sulphate Test After Sensitizing at 1200° F.



Hydrogen Contamination of Titanium Minimized by Modified Descaling Bath

*By H. L. ALEXANDER, H. FARRELL and Q. D. WHEATLEY**

Saturation of sodium hydride baths with titanium dioxide minimizes hydrogen pick-up during descaling of titanium. The coarser grades of titanium dioxide should be used and must be added slowly to avoid excessive foaming and gas evolution. (L 12, Ti)

Hydrogen contamination of titanium and its alloys has been a major problem for producers and fabricators because high hydrogen concentration can cause low ductility and brittle failure of titanium components. One important source of hydrogen is the sodium hydride descaling bath where appreciable amounts are absorbed when the metal is immersed for a longer period than is required to remove the scale.

Barth and Feild found that time in the hydride bath was the most important factor in determining the amount of hydrogen absorbed, although both composition and temperature of the bath had some influence. Their investigation, reported in August 1955 issue of *Metal Progress*, indicated that the only way to minimize contamination was to get the titanium out of the bath as soon as scale was removed. In the same issue, a brief note was included that outlined our preliminary findings in a concurrent investigation which indicated that titanium dioxide additions to the bath might solve the problem. Since then we

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Table I – Hydrogen Absorption and Metal Loss by Titanium in the Sodium Hydride Bath at 740° F.

Sample	NaH	Immersion Time	Weight Loss Mg. per Sq.Cm.	Hydrogen Pick-Up*
1	1.8%	5 min.	1.50	141 ppm.
2	1.8	10	3.71	211
3	1.7	20	7.48	629
4	1.7	40	13.1	1339

*Base level hydrogen is 130 parts per million.

have studied the modified bath intensively and our investigations indicate that titanium dioxide additions do reduce hydrogen pick-up and metal loss without having an adverse effect on the efficiency of descaling.

Examination of the possible equilibria presumed to exist among the components of the hydride bath and titanium, and thermodynamic calculations based on these, do not suggest an obvious modification of the bath that would inhibit hydrogen pick-up. Experience with the commercial hydride baths has shown, however, that old units are generally less corrosive to titanium than new ones and there is a strong correlation between corrosion rate and hydrogen pick-up as shown in Table I. Hence experiments to establish the significance of the concentration of titanium compounds in the bath were made.

Samples of commercial-purity titanium sheet, 0.021 in. thick, were treated in a conventional hydride bath that had been modified by the addition of titanium dioxide. Several levels of titanium dioxide concentration, hydride concentration, temperature and immersion time were studied. Each sample was water quenched and given a short brightening pickle in mixed nitric-hydrofluoric acids prior to analysis for hydrogen content. Blanks to establish original hydrogen content were taken from areas of the sheet immediately adjacent to each test piece. Hydrogen analyses were performed by the equilibrium-pressure method.

Metal attack and hydrogen pick-up data from these tests are given in Table II. In Fig. 1 the metal losses and hydrogen pick-ups for 20-min. exposures are plotted as a function of the titanium dioxide concentration in the bath. The effect of immersion time on hydrogen absorption in the standard and modified baths is shown in Fig. 2.

It is apparent that addition of titanium dioxide to the hydride bath markedly decreases hydrogen absorption and metal loss. If sufficient titanium dioxide is present, hydrogen absorption is virtually independent of the other experimental

Table II – Hydrogen Absorption and Metal Loss by Titanium in the Modified Hydride Bath

Bath Composition			Immersion Time	Temperature	Pickle Time	Weight Loss) (Mg. per Sq.Cm.	Hydrogen Pick-Up†
TiO_2*	NaH	Na_2CO_3					
0.08%	1.7%	2%	20 min.	740° F.	1 min.	5.73	205 ppm.
0.16	2.0	15	20	740	1	3.24	221
0.16	2.0	15	20	740	1	3.24	228
0.20	1.7	15	20	740	1	1.10	30
0.20	1.7	15	20	740	1	1.10	26
0.30	1.7	15	20	700	1	0.40	22
0.33	1.0	15	20	700	1	0.62	18
0.43	1.7	15	20	740	2	0.71	17
0.43	1.7	15	20	740	1	0.45	—
0.43	1.0	15	20	740	1	0.66	12
0.43	1.0	15	20	740	1	0.66	—
0.48	1.7	2	5	740	¼	1.09	8
0.48	1.7	2	10	740	¼	1.17	9
0.48	1.7	2	20	740	¼	1.49	19
0.48	1.7	2	40	740	¼	1.30	23
0.51	1.8	15	20	740	2	1.00	17
0.51	1.8	15	20	740	1	0.63	18
1.00	0.9	2	40	802	¼	1.97	15
1.79	1.5	2	40	797	¼	1.56	28

*Amount added to bath. The bath is saturated when the melt contains the equivalent of about 0.30 to 0.35% dissolved TiO_2.

†Base level hydrogen is 130 parts per million.

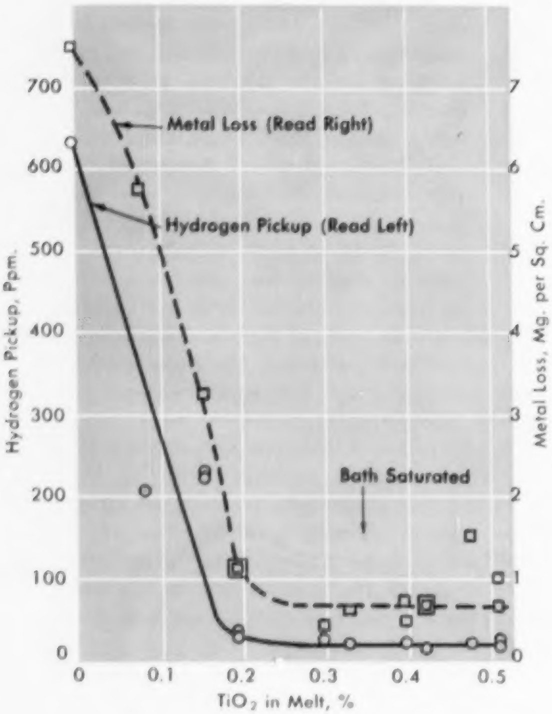


Fig. 1 – Effect of Titanium Dioxide Additions to Sodium Hydride Baths on Hydrogen Pick-up and Metal Loss by Titanium. Immersion time 20 min.; temperature 700 to 750° F.; NaH 1.0 to 2.0%

variables. Since the effect of titanium dioxide was not known at the time of Barth and Feild's work, they did not attempt to control this variable. For this reason no direct comparison can be made between our data and theirs.

Pigment grades of titanium dioxide must not be used to convert commercial hydride baths to the modified composition. Reaction between the molten salt and pigment grade titanium dioxide is so vigorous that the bath may boil over. Coarser grades of material, such as du Pont's "Ti-Pure" VG titanium dioxide, are entirely satisfactory provided that certain precautions are observed.

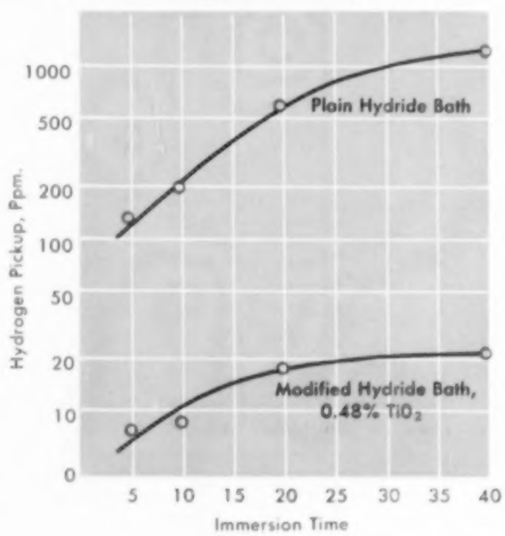
Titanium dioxide reacts exothermally with molten caustic to give titanates and water. The water formed reacts with hydride to form hydrogen. The addition of titanium dioxide should be made cautiously to avoid excessive foaming and too rapid hydrogen evolution. The hazard of gas explosions can be minimized by placing pilot lights near the bath surface to ignite the hydrogen if it is evolved so rapidly that dangerous concentrations could build up. At the same time the rate of addition should be kept low enough to control foaming. A bath temperature of 725 to 750° F. is recommended. If a floating charcoal cover is present, it should be removed before additions of titanium dioxide are made. This will prevent formation of a stable foam.

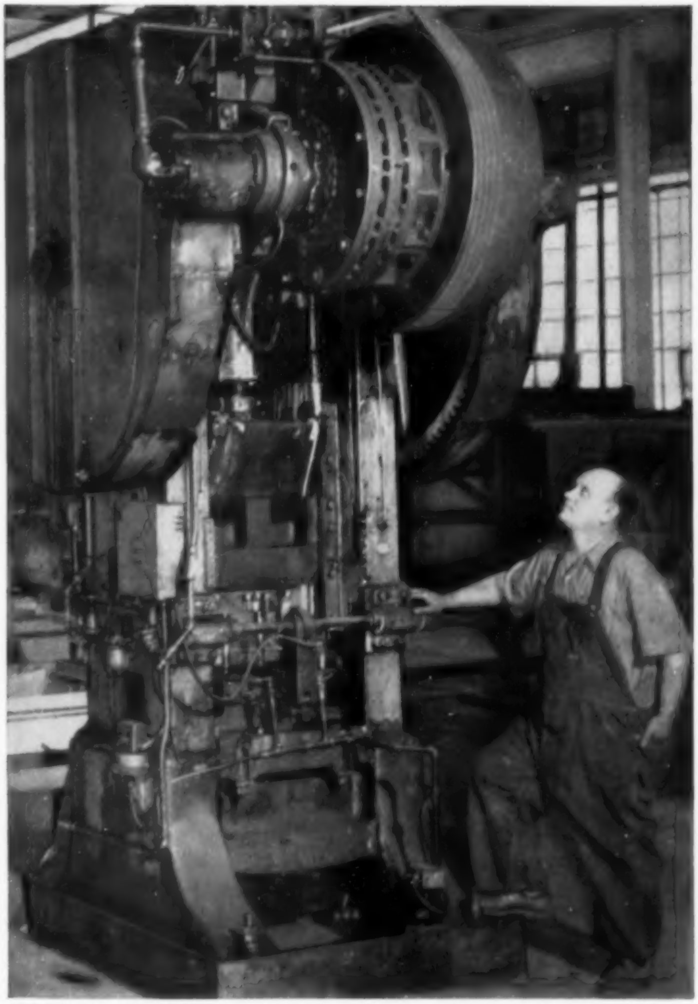
Optimum performance is obtained when the bath is saturated with the alkali metal titanates formed when titanium dioxide reacts with the melt. This point is reached when the melt contains the equivalent of about 0.30 to 0.35% TiO_2. The bath can be controlled and maintained simply by adding, on a regular schedule, enough titanium dioxide to keep the bath saturated. The amount of titanium dioxide to be added is calculated from the amounts of caustic added to replace dragout, and sodium fed to the hydride generators.

The modified hydride bath is now being used commercially to descale a wide variety of stainless and high-alloy steels, titanium and titanium alloys. The modified bath removes the scale from all these materials just as well as the conventional hydride bath.

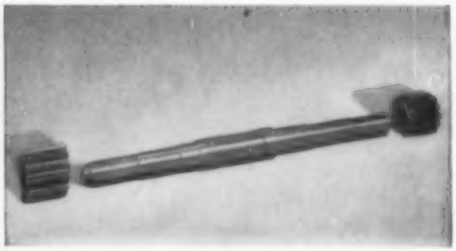
Hydrogen absorption by titanium alloys descaled in the modified hydride bath is currently being studied. Preliminary reports from one user indicate that the modified hydride bath gives very little hydrogen pick-up with a variety of titanium alloys as well as with commercial-purity titanium.

Fig. 2 – Hydrogen Absorbed by Titanium in the Plain and Modified Sodium Hydride Baths

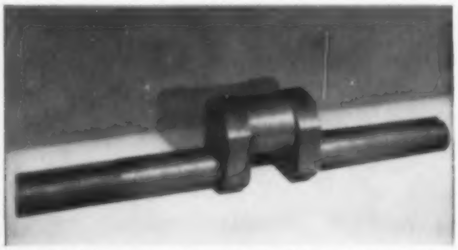




Output up...costs down in plant operating eight presses with Ductile Cast Iron dies, shafts, gears, drums, shoes and the like. State Foundry and Machine Co., Cedar Grove, Wisc., licensed by Inco to produce Ductile Cast Iron, turns out replacements that far outlast previously used materials.



Breakage problem solved. Ductile Cast Iron used on all 8 presses for backshafts. 5' long and 6" at widest diameter, with 1" air hole in center bore, Ductile Iron units need no 8-hour replacement jobs every two months.



Longer life comes from strength and toughness of Ductile Cast Iron. Yet you can readily machine the fine-grained, wear-resistant Ductile Cast Iron used for this heavy-duty crankshaft.

Still good after stamping 875,000 blanks (left) into cases (right). This Ductile Cast Iron die, oil quenched from 1750°F, and stress-relieved at 375°F, develops 55-58 Rockwell C.

Engineers extend life of press parts... up to 18 times with Ductile Cast Iron

IMPRESSIVE RECORDS come from eight 135-ton presses that stamp out 20-mm cartridge cases.

1. Where tool steel dies averaged forty to sixty thousand cases . . .

875,000 cases are now punched out by Ductile Cast Iron dies.

2. Where steel backshafts supporting 3000-pound clutch assemblies failed in about two months . . .

Ductile Cast Iron backshafts have so far served 10 months.

3. Where gray iron brake drums lasted six months maximum . . .

Ductile Cast Iron replacements still operate after 18 months.

Other advantages

As press parts of cast iron and steel wore out or broke, Ductile Cast Iron replacements took over. That reduced downtime, production costs and maintenance, too.

Despite its high wear resistance, Ductile Cast Iron is easy to machine. This advantage saves both time and labor . . . a factor to consider in selecting material for almost any application.

Now replacing more costly materials in many fields, Ductile Cast Iron behaves better in the shop as well as on the job. Get the full story of this economical iron. It's several times stronger than gray cast iron and up to 12 times tougher. Send for a copy of "DUCTILE IRON, The Cast Iron THAT CAN BE BENT!" It's filled with helpful data. Write for your copy now.

ductile iron . . the cast iron that can be twisted and bent

The INTERNATIONAL NICKEL COMPANY, Inc.
67 Wall Street, New York 5, N. Y.

Approximate Strength of Industrial Gas Turbine Alloys Treated for Optimum Properties

Temperature, °F	Tensile Test: Strength Psi.	Tensile Test: Elongation % in 2 In.	Stress-Rupture: 1000 Hr	Stress-Rupture: 10,000 Hr	Creep*: 1% in 10,000 Hr	Creep*: 1% in 100,000 Hr
19-9 DL; A.M.S. 5720A, 5722A, 5727 (Forged) 66 Fe, 19 Cr, 9 Ni, 1.4 Mo, 1.4 W, 1.2 Mn, 0.5 Si, 0.5 Cu, 0.4 Cb+Ti, 0.3 C, 0.25 Ti						
70	130,000	55				
1000	85,000	43	55,000	47,000	40,000	19,000
1100	79,000	42	46,000	40,000	24,000	12,000
1200	73,000	33	35,000	31,000	20,000	10,000
1300	62,000	22	21,000	17,000	13,000	6,000
1400	52,000	35	12,000	8,000	8,000	
1500	30,000	53	9,000	4,500		
A.I.S.I. Type 321 Stainless Steel (Forged) 72 Fe, 18 Cr, 9 Ni, 0.6 Ti, 0.07 C						
70	85,000	55				
1000	53,000	40			18,000	
1100	50,000	43	27,000	16,000	13,000	
1200	44,000	48	17,500	10,000	8,000	
1300	36,000	56	10,000	6,000	5,000	
1400	28,000	64	5,600	3,500	2,000	
1500	22,000	73	3,700	2,000		
A.I.S.I. Type 347 Stainless Steel (Forged) 71 Fe, 18 Cr, 10 Ni, 0.7 Cb, 0.07 C						
70	90,000	50				
1000	61,000				19,000	
1100	57,000	39	30,000	21,000	16,000	14,000
1200	50,000	44	17,000	11,000	10,000	6,000
1300	40,000	51	11,000	6,000	5,000	3,000
1400	31,000	61	7,500	3,500	3,000	1,800
1500	24,000	76	4,200	2,500		
A.I.S.I. Type 410 Stainless Steel (Forged) 85 Fe, 12 Cr, 1 Mn, 1 Si, 0.15 C						
70	145,000	30				
900			34,000	26,000	24,000	12,000
1000	50,000	30	18,000	13,000	11,000	7,000
1100	34,000	45	10,000	7,000	5,000	3,000
1200	20,000	55			2,000	1,300
S-590, A.M.S. 5533, 5770 (Forged) 26 Fe, 20 Co, 20 Al, 19.7 Ni, 4 Mo, 4 W, 4 Cb, 1.5 Mn, 0.4 Si, 0.4 C						
70	138,000	24				
1000	129,000	15	74,000	60,000	47,000	
1100	112,000	20	56,000	43,000	38,000	
1200	98,000	25	40,000	29,000	29,000	22,000
1300	80,000	30	27,000	20,000	22,000	15,000
1400	66,000	32	20,000	14,000	15,000	10,000
1500	53,000	30	15,000	10,000	11,000	7,000
1600	41,000	27	10,000	7,000	8,000	

Temperature, °F	Tensile Test: Strength Psi.	Tensile Test: Elongation % in 2 In.	Stress-Rupture: 1000 Hr	Stress-Rupture: 10,000 Hr	Creep*: 1% in 10,000 Hr	Creep*: 1% in 100,000 Hr
N-155 (Low Carbon), Multimet; A.M.S. 5767, 5768 (Forged) 30 Fe, 21 Cr, 19 Ni, 19 Co, 3.2 Mo, 2 W, 1.64 Mn, 1.1 Cb, 0.39 Si, 0.12 N, 0.12 C						
70	120,000	40				
1200	80,000	32	38,000	25,000	29,000	22,000
1300	70,000	32	29,000	17,000	17,000	14,000
1400	60,000	32	20,000	12,000	13,000	9,000
1500	50,000	33	13,000	7,000	9,000	6,000
Haynes Alloy 21; Vitallium; A.M.S. 5385 (Cast) 62 Co, 28 Cr, 5.5 Mo, 2.5 Ni, 1.7 Fe, 0.28 C						
70	108,000	5				
1200	80,000	10			23,000	
1300	76,000	12	24,000	18,000	18,000	10,000
1400	71,000	15	17,000	14,000	13,000	5,000
1500	62,000	20	14,000	11,000	9,000	
1600	53,000	23	12,000	8,000	6,000	
1700	40,000	25	10,000	7,000		
Timken 17-22-AS; Cyclops 14 MV (Forged) 97.7 Fe, 1.2 Cr, 0.5 Mo, 0.3 C, 0.25 V						
70	153,000	18				
900	118,000	19			52,000	40,000
1000	108,000	20	62,000	32,000	33,000	18,000
1100	93,000	23	23,000	13,000		
1200	75,000	22	7,000			
Timken 16-25-6; A.M.S. 5725, 5727, 5728 (Forged) 50 Fe, 25 Ni, 16 Cr, 6 Mo, 1.9 Mn, 0.6 Si, 0.15 N, 0.08 C						
70	135,000	20				
1000	98,000	23	72,000	65,000	35,000	24,000
1100	95,000	21	50,000	40,000	28,000	18,000
1200	85,000	19	33,000	24,000	22,000	13,000
1300	74,000	19	22,000	14,000	15,000	9,000
1400	58,000	22	14,000	8,000	10,000	7,000
1500	42,000	24	9,000	5,000	6,000	4,000
A.C.I. Type HT; 35-15 (Cast) 46 Fe, 35 Ni, 16 Cr, 1.3 Si, 0.8 Mn, 0.56 C						
70	68,000	10				
1400	34,000	15	12,000	10,000	8,000	
1500	26,000	21	9,000		6,500	
1600	18,000	28	7,000	5,000	5,000	
1800	11,000	27	3,000		2,000	

*Secondary Creep Rate

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WITH AEROHEAT® 1200

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How Statistical Techniques Solve Metalworking Problems Part I

*By CHESTER R. SMITH**

Both time and money can be saved by using statistical techniques to analyze and minimize the necessary experimental data. Two examples of the techniques illustrate how the best methods of processing titanium were selected with a minimum of expense. (S 12, Ti)

IN THE PAST 20 years statistical techniques have contributed tremendously to greater industrial production at a higher level of quality than was ever thought possible. Statistical quality control techniques have been discussed in many articles, and numerous textbooks and publications discuss thoroughly the theory and application of average and range charts.

These charts are used to determine scientifically whether measurements taken on manufactured parts conform to a natural or normal pattern of variation. Limits, based upon past data, are calculated and drawn on these charts so that measurements taken on future manufactured parts can be termed normal or non-normal. The non-normal measurements will be outside the limits drawn and will indicate whether the process average has changed or whether the variability has changed – or both.

From the facts that these charts show about a manufacturing process, engineers can take steps to improve the quality of parts produced. The reason for out-of-control processes can be traced to three general sources – Men, Machines, or Materials, termed the three M's.

With control charts, sampling plans are employed as a basis of decision. The size of samples, the average quality level, and all of the other factors to be considered in sampling are either calculated from past data, preset, or determined from the sampling tables. The MIL-STD 105 sampling tables are perhaps the most well known and most widely used of the many available.

The second category of statistical techniques – analysis of variance, design of experiments, correlation and prediction – is probably the least used in manufacturing plants. However, it is quite understandable, since these techniques are not as easily understood as the charts and require calculations of mathematical formulas. The benefits from these techniques, however, can be more rewarding in dollars saved than the chart techniques.

Just as variability or variations of measurements are the basis of chart techniques, so are they the basis of analysis of variance and design of experiments. In the chart techniques, changes from the constant-cause system are not desirable since an out-of-control situation exists. When the process is out of control, it is necessary to investigate, locate and remove the cause of the excess variability, or the cause of change in the process average. However, in a designed experiment, some factor is purposely changed in order to ascertain its effect, if any, on the constant-cause system.

In a designed experiment, one or more variables are purposely changed and the shift in average, or shift in variability, is analyzed. A designed experiment is usually analyzed by the analysis-of-variance technique. This tech-

*Mallory-Sharon Titanium Corp., Niles, Ohio.

nique, however, can be applied to data which were taken in the shop and not from a designed experiment. Examples of each will be shown.

Control charts are constructed to detect changes in the process average or changes in the process variability; likewise the analysis-of-variance techniques are used for the same purpose. For example, without too much scrutiny or calculation, it is apparent that there is a difference in the averages of Set A and Set B data, but that the variability in each set is about the same.

Set A	Set B	Set C	Set D
21	46	45	22
19	48	46	87
20	44	48	56
22	43	48	41
17	47	51	32

Likewise, it is obvious that the variability in Set D is much greater than the variability in Set C. But what about the averages? By calculation the averages are identical but this is not easily determined by just a glance. Instead, the averages have to be calculated.

With more numbers, as in Table I, calculations are necessary to determine both the average and variability. The averages are a simple calculation; but the question arises, how should we measure the variability? Mathematicians and statisticians have developed the formula shown which gives a measure of variability, called sigma (Greek letter σ), the standard deviation.

The formula may appear quite laborious but the computations are accomplished on a calculator in a matter of minutes. The reason that this sigma-variability calculation is used instead of the range (largest number minus the smallest) or some other measure is that the standard deviation, sigma, is not easily influenced in its magnitude by an extreme value.

Table I – Determination of Standard Deviation

Process Measurements

28	56	52
35	61	48
46	39	31

Standard deviation (σ) is equal to the square root of the sums of squares of each reading minus the average reading divided by the number of readings. In symbols:

$$\sigma = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{n}}$$

Where x_i = each individual reading
$\bar{x}$ = the average of the readings
n = the number of readings
Σ = the sum

For these data, sigma is calculated by:

$$\sigma = \sqrt{\frac{(28-44)^2+(35-44)^2+(46-44)^2+(56-44)^2+(39-44)^2+(52-44)^2+(48-44)^2+(31-44)^2}{9}}$$

$$\sigma = 10.8$$

The practical value of the analysis-of-variance technique can be demonstrated by the following example taken from data accumulated by the Mallory-Sharon Titanium Corp.

One method (A) of processing titanium was being used and a second method (B) was suggested. The difference between the two methods could produce a difference in hydrogen content of the finished material. Before changing to method B, which was cheaper, it was desirable to know if a significant change in the hydrogen content would occur. A low hydrogen content was desirable.

The research group designed the following experiment:

A sheet of titanium was selected at random and cut into 40 pieces. Each of these 40 pieces was then randomly selected to be processed either by method A or method B. After processing, the samples were all measured for their hydrogen contents, and the results were recorded as shown in Table II. The calculations on these data proceeded as follows:

1. The average of each of the two methods was calculated.

2. The *variance* of each set of data was then calculated. The variance is merely the value obtained in the formula for sigma before the square root has been taken, and with (n-1) in the denominator. When comparisons are made between two sets of data, the variance is calculated rather than the standard deviation.

3. The *degrees of freedom* are determined next. The degrees of freedom have been defined mathematically, and for this analysis they are one less than the number of readings which were used to obtain the variance.

4. From the data, we now form what is termed an "F-ratio". This ratio is calculated by dividing the largest variance by the smallest variance. In our example this F-ratio would be equal to 144.80 ÷ 89.60, which equals 1.62.

5. This F-ratio is used in order to answer the

Table II – Hydrogen Content in Titanium After Processing

Hydrogen From Method A (in parts per million)				Hydrogen From Method B (in parts per million)			
87	102	104	109	71	74	85	108
105	81	89	98	86	102	107	106
99	85	96	84	111	98	95	87
84	93	75	100	87	79	95	111
78	97	83	91	93	94	99	112
Sum = 1840 ppm.				Sum = 1900 ppm.			
Number = 20 readings				Number = 20 readings			
Average = 92.0 ppm.				Average = 95.0 ppm.			
Variance = 89.60				Variance = 144.80			
Degrees of Freedom = 19				Degrees of Freedom = 19			

first question about our two samples: Can we say that the two samples exhibit the same relative amount of variability? As can be seen from the value of "F" obtained, sample B is 1.62 times as variable as sample A. In order to answer whether this amount of relative variability is significant or not, we use a table of F-values,* and determine a limit of the F-ratio with these particular degrees of freedom.

We enter the F-table across the top with the number of degrees of freedom in the numerator – variance used in the F-ratio – for our example, 19. We then come down the left-hand side of the table until we come to the denominator-variance degrees of freedom – our example is 19. Where this column and row intersect, we read two values, as follows:

$$F\ (0.05\ \text{level}) = 2.16$$
$$F\ (0.01\ \text{level}) = 3.03$$

The difference between the 0.05 level and the 0.01 level is dependent upon what percentage risk we are willing to take that we will say the samples do not exhibit significantly different variances when really they are significantly different.

At either level, the F-ratio is not significant since the calculated F-ratio is less than the limit of the F-ratio obtained from the table. Therefore, we say that the two samples do not exhibit significantly different variances. In terms of our two processes, A and B, each produces about the same amount of variability in the final hydrogen content of titanium sheets.

6. The second question, concerning the averages of the two methods, can now be answered in the following manner: We calculate a "t-Value" from the following formula:

$$t = \frac{\bar{X}_A - \bar{X}_B}{\sqrt{\dfrac{n_A \, Var\,(A) + n_B \, Var\,(B)}{n_A + n_B - 2}} \sqrt{\dfrac{1}{n_A} + \dfrac{1}{n_B}}}$$

For our example, the formula would be solved as follows:

$$t = \frac{92.0\ ppm - 95.0\ ppm}{\sqrt{\dfrac{20\,(89.60\ ppm^2) + 20\,(144.80\ ppm^2)}{20+20-2}} \sqrt{\dfrac{1}{20} + \dfrac{1}{20}}}$$
$$= \frac{-3\ ppm.}{3.521\ ppm}$$
$$= -0.85$$

The minus sign is not significant since we could have subtracted $\bar{X}_A$ from $\bar{X}_B$ and obtained the same value, only positive.

This calculated t-value is now compared to a table of t-values† to ascertain whether the 3-ppm. difference in the two averages is significant or could have occurred by chance alone. We enter the t-table across the top at the desired risk level we can afford; in our example let's assume it is 0.05. We then come down to the left-hand column until we reach the number corresponding to the degrees of freedom. (We use 19 + 19 = 38 degrees of freedom.) Where the column and row intersect we read the t-value of ± 1.645.

We then compare our calculated t-value of – 0.85 to the table value of ± 1.645. Since the calculated value does not exceed the limit-value shown in the table, we can say that methods A and B do not produce significantly different average hydrogen contents. We can now conclude that method B is desirable, since the hydrogen contents obtained from using method B are not significantly higher than the hydrogen contents obtained using method A, and method B is cheaper.

What was this experiment worth? The entire cost including the material, labor, hydrogen analysis, and statistical analysis was approximately $300. It was done in parts of three days.

If the production process had been changed to method B, and data collected, the experiment alone would probably have cost twice this amount and would have taken twice the amount of time. If it had been run on production material, it could have ruined thousands of dollars worth of titanium before enough data were collected and analyzed to label process B detrimental.

The preceding example dealt with only one factor at two different levels, namely, hydrogen

*"Mathematics of Statistics" Part II: by J. F. Kenny and E. S. Keeping, D. Van Nostrand Co., Inc., New York; Second Edition, 1951, p. 410 to 413.

†Kenny and Keeping, p. 416 and 417.

content from levels A and B of processing. The next example deals with two factors at each of two levels.

The data shown in Table III were accumulated by the Mallory-Sharon Titanium Corp. inspection group from a pickling operation. They were arranged in a table where two different pickling times had been used at two different temperatures of the pickling bath. Each reading was the thickness of metal lost, expressed in 0.001 in. The problems were:

1. Is there a significant difference in the amount of metal removed using the times in the bath of 2 and 5 min.?

2. Is there a significant difference in the amount of metal removed using the temperatures of the bath of 90 and 140° F.?

3. Is there a significant interaction between time and temperature which affects the amount of metal removed?

There are four possibilities of variation in the readings which were obtained: the difference in time; the difference in temperatures; variation in the readings for a given temperature and given time; and the interaction of time and temperature. The sum of all these variations gives the total variability.

The degrees of freedom can be determined for each of these sources of variability. For the total, we have 4 cells with 4 readings in each, which equals 16 total readings. Then by our former statement about degrees of freedom, there are 15 in this example. Next, for the within-cells source, we have 4 cells, with 4 readings in each; therefore, each cell has 3 degrees of freedom, or a total of 4 × 3 equals 12 degrees of freedom. The interaction degrees of freedom are usually obtained by subtraction; that is, the total degrees of freedom minus all of the other degrees of freedom. For the between-times variability, there are only two different times; therefore, the degrees of freedom are only one. The same is true for temperatures. We therefore calculate the interaction degrees of freedom as the total, 15, minus the within-cells, 12, minus the between-times, 1, minus the between-temperatures, 1, which leaves 1 for the interaction.

We now come to the calculations of the variabilities. A rather convenient short-cut method for the calculations has been developed mathematically. Justification of these equations will not be shown, since our purpose is to show a technique of analysis of variance.

To use the formulas for calculations, we make the following computations:

1. We add up all the readings in each cell. These are called $T_{ij.}$'s (read T i j dots).

2. We add up all the readings for each time, regardless of temperatures. These are called $T_{i..}$'s (read T i dot dots).

3. We add up all the readings for each temperature, regardless of times. These are called $T_{.j.}$'s (read T dot j dots).

4. We add up all of the readings in the table. This is called $T_{...}$ (read T dot dot dot).

5. We calculate the sum of all the readings squared. (Square each reading and then add them up.)

For use of the formulas, we now define three simple quantities:

m = number of readings in each cell = 4

l = number of rows in the table (2 temps.) = 2

k = number of columns in table (2 times) = 2

We can now use the following set of formulas and compute from them what are termed the "Sums of Squares".

1. Total Sum of Squares (abbreviated T.S.S.):

T.S.S. = Sum of all readings squared

$$\text{minus } \frac{T_{...}^2}{klm}$$

$$= 158.44 - \frac{(49.6)^2}{4 \times 2 \times 2}$$

$$= 158.44 - 153.76$$

$$= 4.6800$$

2. For ease of calculation, we now compute what is termed a "Subtotal Sum of Squares" (abbreviated S.S.S.):

$$\text{S.S.S.} = \text{Sum } \frac{T_{ij.}^2}{m} - \frac{T_{...}^2}{klm}$$

$$= \frac{11.9^2 + 10.6^2 + 12.2^2 + 14.9^2}{4} - 153.76$$

Table III – Effect of Time and Temperature of Pickling on Amount of Metal Removed

Temp.	Time: 2 Min. in Bath	Time: 5 Min. in Bath	
90° F.	2.5	2.8	
	3.6	2.1	
	2.7	3.3	
	3.1	2.4	
	Tij. = 11.9	Tij. = 10.6	T.j. = 22.5
140	3.2	4.2	
	2.9	3.8	
	3.4	3.6	
	2.7	3.3	
	Tij. = 12.2	Tij. = 14.9	T.j. = 27.1
	Ti.. = 24.1	Ti.. = 25.5	T... = 49.6

Sum of the readings squared = 158.44.

Table IV—Analysis of Variance

Source of Variability	Degrees of Freedom	Sum of Squares	Mean Square
Between the times	1	0.1225	0.1225
Between the temperatures	1	1.3225	1.3225
Interaction of time and temperature	1	1.0000	1.0000*
Within cells	12	2.235	0.1862
Total	15	4.6800	

$$= \frac{624.82}{4} - 153.76$$
$$= 156.2050 - 153.76$$
$$= 2.4450$$

3. Within-Cells Sum of Squares (abbreviated W.S.S.):

$$\text{W.S.S.} = \text{T.S.S.} - \text{S.S.S.}$$
$$= 4.5800 - 2.445$$
$$= 2.2350$$

4. Between-Times (or Columns) Sum of Squares (abbreviated B.C.S.S.):

$$\text{B.C.S.S.} = \frac{\text{Sum } T_{j..}^2}{lm} - \frac{T_{...}^2}{klm}$$
$$= \frac{24.1^2 + 25.5^2}{4 \times 2} - 153.76$$
$$= \frac{1231.06}{8} - 153.76$$
$$= 153.8825 - 153.76$$
$$= 0.1225$$

5. Between-Temperatures (or Rows) Sum of Squares (abbreviated B.R.S.S.):

$$\text{B.R.S.S.} = \text{Sum } \frac{T_{.j.}^2}{km} - \frac{T_{...}^2}{klm}$$
$$= \frac{22.5^2 + 27.1^2}{4 \times 2} - 153.76$$
$$= \frac{1240.66}{8} - 153.76$$
$$= 155.0825 - 153.76$$
$$= 1.3225$$

6. Interaction Sum of Squares (abbreviated I.S.S.):

$$\text{I.S.S.} = \text{S.S.S.} - \text{B.C.S.S.} - \text{B.R.S.S.}$$
$$= 2.4450 - 0.1225 - 1.3225$$
$$= 1.0000$$

7. We now enter these Sums of Squares in the Table of Analysis of Variance (Table IV) and include degrees of freedom and the Mean Square, obtained by dividing the sums of squares by their respective degrees of freedom. Note that we do *not* calculate a mean square for the total variability. We now form F-ratios as follows:

1. Interaction:

$$F = \frac{\text{Interaction Mean Square}}{\text{Within-Cells Mean Square}}$$
$$= \frac{1.0000}{0.1862}$$
$$= 5.37$$

F (0.05 level) $= 4.75$

F (0.01 level) $= 9.33$

The calculated F-ratio is significant at the 0.05 level, but not at the 0.01 level. As a convenient notation, we will denote in a final right-hand column in our Analysis of Variance table that the variabilities significant at the 0.05 level will have one star (*), and those variabilities significant at 0.01 level will have two stars (**). Therefore, we one-star the F-ratio for the interaction.

2. Between Temperatures:

$$F = \frac{\text{Between-Temperatures Mean Square}}{\text{Interaction Mean Square}}$$
$$= \frac{1.3225}{1.0000}$$
$$= 1.3225$$

F (0.05 level) $= 161.00$

F (0.01 level) $= 4{,}052.00$ (not significant)

3. Between Times:

$$F = \frac{\text{Between-Times Mean Square}}{\text{Interaction Mean Square}}$$
$$= \frac{0.1225}{1.0000}$$
$$= 0.1225$$

F (0.05 level) $= 161.00$

F (0.01 level) $= 4{,}052.00$ (not significant)

The conclusions from the analysis are now rather straight-forward.

1. Time in the bath, alone, produces no significant effect on the amount of metal removed in the pickling bath.

2. Temperature of the bath, alone, produces no significant effect on the amount of metal removed in the bath.

3. The interaction of time and temperature *does* produce a significant effect on the amount of metal removed.

Reflect, for just a moment, on what would have happened if the two variables of time and temperature had been investigated separately. No significant effect on the variability of metal removal in the pickling operation would have been found; this would have been a very erroneous conclusion concerning the behavior of the pickling operation. Much confusion could have resulted at a later date when it was discovered

that the interaction did exist; meanwhile, many dollars worth of material could have been lost due to an uncontrolled metal removal.

These two examples have been used to demonstrate statistical techniques. It was not the intention of this article to exploit the theory of analysis, but rather to stimulate an interest in the use of analytical techniques.

In the second article we will discuss a multiple-factor design and analysis of a research experiment in the study of the effects of alloying agents in titanium.

Conversion Coatings for Cadmium and Zinc

*By EDWARD F. FOLEY, JR.**

Conversion coatings are economical and versatile finishes for cadmium and zinc-plated parts and zinc-base die castings. They are formed by chemical reaction between the metal surface and a suitable solution. With minor modifications in the processing conditions a wide range of surface finishes can be obtained. No expensive equipment is required. (L 14, Cd, Zn)

Conversion coatings for cadmium and zinc became popular during the shortage caused by our last series of military conflicts when they were used as substitutes for finishes which had become unavailable. Today they are no longer specified as substitutes but are used to improve corrosion resistance, prevent fingerprint stains, produce attractively colored surfaces, reduce reflectivity and last, but probably most important, to increase the adhesion of organic coatings such as paints, lacquers and enamels. Their low cost makes them ideal for finishing items which must meet close price competition.

A conversion coating is any inorganic coating other than a metal formed by galvanic action. The chromates, phosphates, molybdates and sulphides are the most frequently used for cadmium and zinc. They are usually produced by simply dipping the part in a suitable solution for a specified time at a controlled temperature. The part is then rinsed and dried. With the phosphates, the solution may sometimes be sprayed or brushed on the surface to produce the coating.

No external electric current is required because of the galvanic action, so racking is not necessary. The work is frequently handled in bulk in baskets or cylinders and should be agitated to prevent bare spots or nonuniform markings where adjacent pieces are in contact.

While production of conversion coatings on a clean, active layer of zinc or cadmium is simple, the process which produces the clean, active

*Research Chemist, Enthone, Inc., New Haven, Connecticut.

surface may be the most expensive part of the cycle. When the coating is applied immediately after electroplating, no trouble is encountered. The preparation is simply a dilute acid dip to neutralize the surface followed by a cold water rinse. Where the work is heavily soiled it must be thoroughly cleaned and activated before going into the coating tank.

Chromate Coatings

The common conversion coatings are listed in the table. The chromates are most widely used for zinc and cadmium. They may be applied to electroplated zinc or cadmium surfaces or to zinc or zinc-base die castings. Their greatest use is on zinc-plated or cadmium-plated steel. The finish varies from the very thin invisible coating (sometimes referred to as bright dip) through the heavier iridescent films to the bronze and olive drab coatings. The various kinds can often be produced from the same mixture of chemical compounds by changing the concentration of the solution, immersion time and the temperature of operation. Immersion times may vary from a few seconds to 15 min.

It is frequently more convenient to use a chromating solution designed to produce only a specific type of coating. While such solutions are more limited in their use, they simplify to some extent the operation of the coating bath, which can usually be used at room temperature. All the solutions used contain hexavalent chromium, generally as chromic acid, with suitable activating agents and catalysts. The wide variety available and their adaptability make it relatively simple to add chromate coatings to an existing finishing cycle at relatively low cost.

The cycle for producing chromate coatings is:

1. Preparation of the surface.
2. Cold water rinse.
3. Immersion in chromating solution at recommended concentration, time and temperature.
4. Cold water rinse.
5. Cold water rinse.
6. Air dry.

For freshly plated zinc or cadmium, the preparation consists of a few seconds immersion in a 2% solution of hydrochloric, sulphuric or nitric acid. Nitric acid has the advantage of brightening the surface but does, however, remove more metal from the surface and is not recommended if brightening is not needed. For cadmium sur-

Characteristics of Conversion Coatings for Cadmium and Zinc

Appearance	Use
Chromate Coatings – Bleached	
Film varies from invisible to iridescent. Appearance varies from bright zinc to bluish tinge similar to chromium plate.	Major use is to improve appearance. It affords light corrosion protection and prevents fingerprint marks. Simulates chromium finish, especially when covered with a clear lacquer.
Chromate Coatings – Unbleached	
Color varies from light iridescent through yellow, bronze to olive drab.	Used to improve the adhesion of organic coatings and increase corrosion resistance. Often specified because of the attractiveness of the color, especially the colors approaching bronze or brass. Olive drab is suitable for military applications. Sometimes used to eliminate reflectivity or glare.
Chromate Coatings – Dyed	
The yellow unbleached finishes can be dyed red, blue and black.	Major use is to provide matching or contrasting colors. Sometimes used as color code to assist in sorting similar but non-interchangeable parts. These coatings also offer excellent corrosion resistance.
Black Molybdate Coatings	
Very dark gray to dead black. Luster (glossy or matte) depends on condition of surface before blackening.	Major uses are for appearance, to eliminate reflectivity or glare, blackening and to increase corrosion resistance.
Black Nickel Sulphide Coatings	
Same as black molybdate.	Same as black molybdate, used where a more ductile coating is desired such as before a crimping operation.
Phosphate Coatings	
Dull gray crystalline finish.	To improve adhesion and corrosion resistance of organic finishes. Many proprietary phosphating solutions function also as cleaners prior to painting.

faces, which are not very active, a solution of ammonium nitrate is sometimes used for activation but this also removes considerable metal.

For zinc die castings or soiled surfaces it is necessary to clean thoroughly before activating with the acid dip. A heavily soiled surface might require cleaning first with an emulsifiable solvent and then an alkaline cleaner. The part should be rinsed in cold water prior to the dilute acid dip.

The bright, invisible coatings afford excellent protection against fingerprint stains. These very thin films are produced by leaching a heavier chromate film in a bath consisting of caustic soda, sodium carbonate or a proprietary leaching solution. Heavier chromate coatings provide much more corrosion protection and require no treatment after formation other than thorough rinsing and air drying.

In salt-spray corrosion tests of zinc-plated steel, white zinc corrosion products appeared on untreated panels in less than 8 hr., while the time required for the appearance of white corrosion products was 24 to 100 hr. for thin, clear chromate coatings, and 100 to 500 hr. for the heavier olive drab coatings. Red rust showed on the untreated panels after 150 to 400 hr., on the thin coated samples in 250 to 500 hr. and after 500 to 1500 hr. for the olive drab coated samples.

All chromate coatings are soft when first formed and do not harden until they are dry. The coating can be wiped off at this stage and parts must be handled carefully. Because of this, they cannot be wiped dry or dried by tumbling, and are dried either by a blast of cold air or in a centrifugal dryer.

These soft films are absorptive and can be dyed in a variety of colors using water soluble dyes. The color is applied immediately after rinsing by placing the part in a solution of dye usually acidified with acetic acid. The work is then rinsed in clear water and allowed to dry. Some of the color is lost on rinsing and the final color will be lighter than when first removed from the dye bath.

Phosphate Coatings

While chromate coatings on cadmium or zinc are an excellent base for organic coatings such as lacquers and paints, phosphates are more often specified for this purpose. Phosphate coatings improve the adhesion of organic coatings and increase the corrosion resistance of the coated metal. They are effective both on zinc-base die castings and on zinc or cadmium-plated steel. Zinc or cadmium-plated steel which has been phosphated has a much higher resistance to corrosion than straight phosphated steel.

The most widely used phosphating baths consist of a mixture of various salts of phosphoric acid along with an accelerating agent, usually an oxidizing agent, and one or more wetting agents. The phosphates used are balanced to yield a solution of the proper hydrogen ion concentration (pH), and in some baths phosphoric acid may be used in addition to the phosphates. The solution dissolves some of the metal from the surface causing an increase in the metal ion concentration at the surface and a change of pH. These reactions cause a precipitation of metal phosphate crystals on the surface of the piece. The rate of growth of these crystals determines the quantity and quality of the phosphate coating produced.

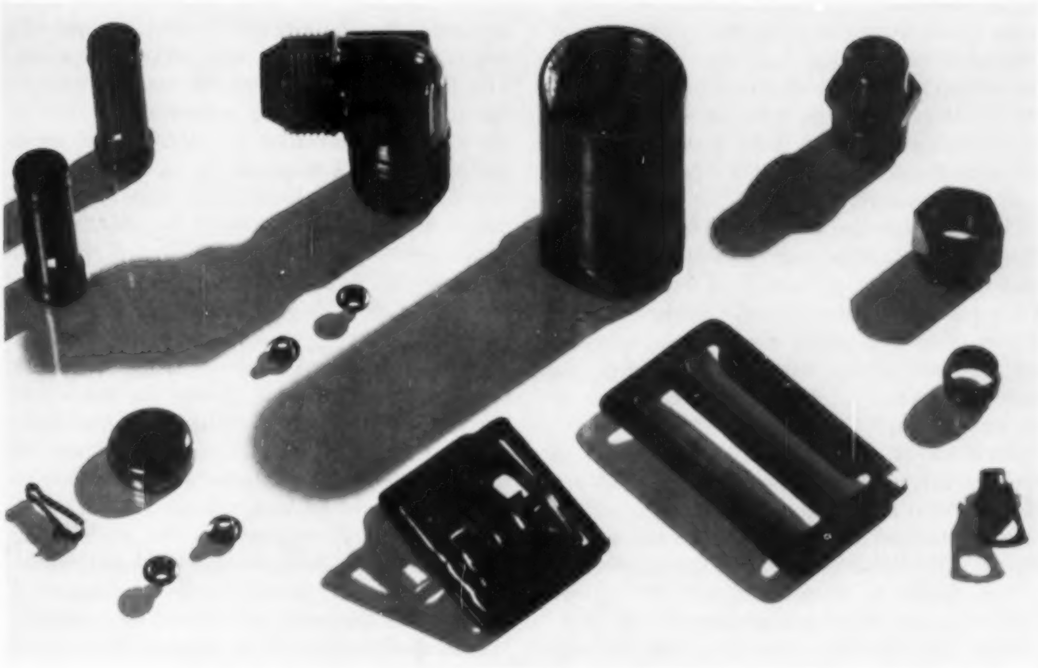
The cycle used for producing phosphate coatings is as follows:

1. Preparation of the surface.
2. Cold water rinse.
3. Immerse, spray or wipe the phosphating solution at the proper concentration, time and temperature.
4. Cold water rinse.
5. Dip in dilute chromic acid.

The final dip is used to produce an acid surface condition to improve adhesion of subsequent organic coatings.

For freshly plated work the only surface preparation necessary is a dip in mild phosphoric acid solution. If the surface is not freshly plated, it must be cleaned and activated before phosphating. Strong alkaline cleaning is not recommended because it tends to make the phosphate coating more granular and less adherent. For this reason many of the proprietary phosphating solutions are designed to function both as a cleaner and a phosphating solution. With this type of solution no pretreatment is necessary for lightly soiled work. Material which is heavily soiled is either vapor degreased or cleaned with an emulsifiable solvent cleaner before being phosphated. If strong alkaline cleaning is necessary it is followed by a neutralization in mild acid, frequently phosphoric or oxalic acid. In writing specifications for zinc or cadmium plating before phosphating, remember that some of the metal is removed from the surface in the phosphating process so a slightly heavier plate is necessary.

A thin, tightly adherent phosphate is better for paint adhesion than a heavy coating. The small dense crystals produced are more efficient



Zinc-Plated Parts Treated With Black Molybdate Conversion Coating

in retarding lateral corrosion between the metal and the organic coating. In addition, less paint is required than with the heavier coatings.

Black Coatings

Black coatings for zinc, other than black dye chromate coatings, can be divided into two classes; black molybdate coatings and black nickel coatings. The molybdate coatings are oxides and the nickel coatings are sulphides.

Black molybdate coatings are produced from solutions of soluble molybdates, with activators, complexing agents and buffers added. A great variety of simple molybdate solutions will produce black coatings on zinc. These coatings, however, are uneven in color, are frequently nonadhesive and may be spotted with white salts which are the result of rapid corrosion of the zinc. A blackening bath to be practical must be designed to maintain the proper pH, control the rate of reaction over the entire surface and prevent the accumulation of free zinc ions in the solution. Most proprietary solutions for blackening zinc meet all these requirements. Some representative zinc-plated parts are shown above.

Zinc or zinc-plated work to be blackened in molybdate solutions must not be put in an uncoated metal basket or be allowed to come in contact with an uncoated metal tank. If an uncoated steel basket were used, it would be cathodic, and blacken in preference to the work. It is sometimes necessary to blacken zinc die castings with small inserts of some other metal such as steel. When the parts are put into the solution the steel will blacken first and after the steel is covered the zinc will blacken. This black on steel is less adherent than the black on zinc, and such a black on copper or brass would be even less adherent. Better results would, of course, be obtained if the whole piece were zinc plated before blackening. While zinc coatings as thin as 0.0001 in. have been successfully blackened, it is generally recommended that at least 0.0002 in. of zinc be applied when the surface is to be blackened. Where zinc plate which is to be blackened is applied primarily for corrosion resistance, at least 0.0001 in. extra should be allowed for the loss of metal in the blackening bath. The preparation for coating is the same as that used in chromating.

After blackening, the work must be rinsed thoroughly, first in cold water and then in hot water. Parts which are normally hard to rinse should be left in the hot water for 2 to 3 min. to leach out any trapped salts. The appearance of white salts on the surface of the work after

drying is usually a sign of insufficient rinsing. If the black coating is to be used as a base for lacquer or enamel, the final rinse may be followed by a dip in very dilute acid. Black molybdate coatings should be dried by blowing with air or drying in corncob meal or sawdust since stains are formed when the hot water is allowed to dry on the work.

The corrosion resistance of blackened zinc-plated steel is a little better than that of blackened zinc die castings because of lower porosity of the plated steel. In general, the black molybdate coatings will stand considerable handling and if used indoors will be satisfactory. For outdoor use some additional protection such as oil, wax or lacquer is needed.

Black nickel coatings consist essentially of black nickel sulphide. The solutions used are soluble nickel salts with either thiocyanates or thiosulphates and a variety of buffers and accelerators. Oxidation of zinc reduces the thiocyanate or thiosulphate to thiosulphide ions. When the concentration of sulphide ions is sufficiently high, black nickel sulphide precipitates on the surface.

The corrosion resistance of sulphide coatings is generally less than that of the oxide coatings. Like the molybdate coating the black nickel coatings require some additional protection when used outdoors. The sulphide coatings are more ductile than the molybdates – an important factor when the finished part must be crimped or bent. As with most other conversion coatings, a bright finish is produced on buffed surfaces. If a dull surface is desired the zinc is either etched or abraded with a greaseless compound or with a wire wheel and pumice. The cycle used for blackening is the same as that used with molybdate coatings.

Preparation for Coating

The problem of cleaning and activating heavily soiled or old zinc and cadmium parts varies according to the type of soil present and the equipment used for cleaning. The greatest difficulty is encountered in cleaning zinc-base die castings. Zinc is soluble in both strong acids and strong bases and both of these leave a nonadherent smut on the surface which interferes with the formation of conversion coatings. This smut is difficult to remove chemically and it is more economical to prevent its formation than to remove it.

The first step should be either cleaning with emulsifiable solvent or vapor degreasing to remove grease, dirt and buffing compounds. When the part has been buffed this is most important since heavily caked buffing compounds are difficult to remove with alkaline cleaners. The first cleaning reduces the over-all time in the alkaline cleaner, thus preventing local etching and smut formation in lightly soiled areas during the time required to clean the more heavily soiled areas. Emulsifiable solvent cleaners followed by a spray rinse have the advantage of removing solid dirt by mechanical action and therefore this type of cleaning is frequently preferred to vapor degreasing.

Alkaline cleaners for zinc-base die castings should be chosen to fit the type of equipment being used and the soil present on the work. Where the work is moved by hand and the cleaning time can be short, stronger cleaners may be used. On automatic machines where the time in the cleaner must be long, a more dilute cleaner must be used. Remember that the more dilute cleaners must be changed more frequently. Most manufacturers of cleaners will recommend a cleaner to fit the cycle and the soil encountered.

The alkaline cleaner is followed by a cold water rinse and a short dip in dilute acid to neutralize the surface. Here again a more dilute acid must be used for the longer immersion time encountered in automatic machines. A 5 to 10% solution of sulphuric or muriatic acid is used for the ordinary cycle, while solutions as dilute as 1% may be used for longer cycles. A long etch in the acid is undesirable; the work should be removed as soon as gassing starts. This cleaning cycle is recommended for zinc-base die castings and, where necessary, for electroplated zinc and cadmium before chromating and before blackening in either the molybdate or black nickel coating baths.

Emulsifiable emulsion cleaners are recommended before phosphating and they serve the same function as described above. Alkaline cleaners should be avoided if possible since their use affects the rate of growth of the phosphate crystal and a very granular coating may be formed. The use of phosphate solutions with built-in cleaners is highly recommended. If it is necessary to use a noncleaning phosphate solution or if the soil is so heavy as to require alkaline cleaning before phosphating, the same cleaners may be used as for chomating. The alkaline cleaner should be followed by a cold water rinse and a short dip in phosphoric acid to neutralize the surface. The use of stronger acids makes the production of fine-grained coatings more difficult.

Correspondence...

Russian Iron and Steel Industry

LONDON, ENGLAND

A party of experts from the British iron and steel industry, under the leadership of Sir Robert Shone, executive member of the Government's Iron and Steel Board, together with representatives from Belgium, France and Sweden, visited Russia during the early autumn of 1955 to see some of the iron and steel plants there. Sir Robert and W. F. Cartwright, assistant managing director of the Steel Co. of Wales, Ltd., reviewed their findings at a meeting of the Iron and Steel Institute in London in November. A more comprehensive report on the expedition will probably be published later.

Sir Robert believes that, at the more modern plants, the output per man is very similar to comparable plants in Britain. Of the plants visited, the two integrated works (Zaporojhe in the Ukraine and Rustavi in Georgia) have a combined annual output of 2,500,000 tons with an employment of 21,500 workers. This figures to 115 tons per man-year, and the output per man at plants at the top end of the British scale, covering about 25% of the output, would be broadly comparable to these two Russian plants, which are also among their better works. But they are still developing and a rapid progress will be needed if output per man in the western countries is to keep pace. Indeed the view is expressed in Russia that they have caught up with Western Europe, but they still lag behind America, and have their sights set on narrowing this gap. Russian steel output will probably reach 50,000,000 tons in 1955 and is expected to rise to 67,500,000 tons in 1960.

Financial incentives are employed to attract labor into the coal and steel industries, where rates are higher than in other industries. They are also 20% higher in Eastern Russia than in Western Russia for a similar reason.

The Russian steel industry has an abundance of relatively cheap iron ore. At Krivoi Rog, the great iron ore center of the Ukraine, the output of 55% ore is a declining proportion of the total output; concentration and sintering of 36% ore is being developed extensively. This ore is mined in open pit, and after treatment to give a 60% sinter, is available at about a third of the present cost of the comparable ores imported into Britain, assuming ore prices are measured by an exchange rate that equates wages in the two countries. So long, too, as the Russian worker accepts half the real standard of living of the British worker and achieves a somewhat comparable level of productivity, Russian industrial products can be sold more cheaply on world markets.

The Krivoi Rog deposit is 160 miles long and about 5 miles wide. The bottom of the deposit is hematite and high in iron, and in the outcrops, or near them, it is magnetite with about 35% iron. At the large new concentration plant they were either making, or going to make, a self-fluxing sinter, bringing in seashells for this purpose.

The undoubtedly great industrial progress in Russia seems to stem from four factors – first, its favorable raw materials; second, its labor

supplies and emphasis on technical and scientific education; third, the use of every possible incentive, particularly financial, to higher productivity; and fourth, the devotion of a large part of the country's resources to capital development rather than to manufacture of goods for the consumer.

W. F. Cartwright, discussing the technical progress in the Russian iron and steel works visited, said that the visitors saw some of their newest and some of their best.

Of the two blast furnace plants inspected, that at Zaporojhe was the most interesting. There are five furnaces, all on high top pressure, blowing at about 27 psi. with about 5 psi. top pressure. They appear to be thinking of working eventually with 100% sinter. All furnaces have 26-ft. hearths but one makes 1100 tons of iron per day and another 1950.

As in all Russian plants, the furnaces are extensively instrumented, the high top pressure instrumentation, for example, being most elaborate. Coke consumption is not as low as might be expected from the ore being used, containing 56 to 58% iron. The coke figure is about 1750 lb. per net ton of iron. Blast pressure is high, the volume of air delivered exceeding 100,000 cu. ft. per min.

There is no doubt that the most interesting plant of those seen was the steelworks at Zaporojhe. It is on American lines with 200-ton fixed furnaces, ten in a row, with two mixers in a separate building. The tap-to-tap time is 7 hr., 45 min. The reasons for these good times are fairly clear. The pig iron is excellent, having 2.7% manganese, 0.7% silicon, 0.18% phosphorus, and 0.04% sulphur. They use 70% molten metal, drawn exactly when required, there being an ample supply. Pig iron production is over 2,200,000 tons and steel production only about 2,000,000 tons. A standard scrap charge consists of 12 buggies, each with four scrap boxes. There is always the same amount of scrap bundles. There is scrap from the motorcar works at Gorki and other mill scrap, limestone and lime, so that the charging is simple and uniform.

Furnaces are fired with mixed blast furnace and coke oven gas, the air being enriched with up to 25% oxygen. In this country that would immediately burn down the furnace roof, but the Russians use chrome-magnesite roofs, not with spring skewbacks and not suspended, but with a very pronounced rise. There was a tremendous array of instruments, and one furnace was being tried out with a double dose of them, including a program control. On one furnace they were blowing the bath down by oxygen through the roof.

The pitside at Zaporojhe was in good shape, and generally speaking the shop was a credit to all concerned. A feeling of great urgency and alertness was apparent on the part of everybody there.

At Rustavi, the steel shop was not in the same class. They had six 125-ton oil-fired furnaces and a mixer. The furnaces were being enlarged to 150 tons. It is not clear why the furnaces are smaller at Rustavi, just as they have smaller blast furnaces there; it would seem that Russians build their plants in proportion, giving a big plant big furnaces and so on. At Rustavi the output appears to average 2800 tons per week per furnace. The average at Zaporojhe, however, is more like 4700, which is quite a difference.

So far as rolling mills are concerned there is not much of interest, and the Russians themselves are conscious of the fact that there is a lot to be done. For example, the 66-in. strip mill at Zaporojhe was made by United about 1936. For its age and type, it was going extremely well, and in the future it will deal with the whole output of the ten-furnace shop, plus some silicon steels made in a nearby shop and some stainless steel made in electric furnaces nearby.

In the cold mill are turned out silicon steel, auto-body sheets, stainless and tin plate. Silicon steels are annealed in vacuum. Tin plate is not rolled thinner than 0.011 in. The head technical man of the concern said they reckoned that the standard strip mill of the future should be planned for an output of 2,800,000 tons a year of hot strip, and on the basis of 40% flat products they would be building quite a number of strip mills in the future.

The standard of the steel which was seen at Zaporojhe and at Rustavi was good. There appeared very little need for any surface dressing, and the steel quality was of the high standard that would be expected from their excellent raw materials. To make tube steel, however, is quite a difficult matter, and the visitors were interested to see two tube plants, where output is mainly seamless tube, concentrating on one type. Nothing was seen which would be regarded as revolutionary in seamless tube plants, but they were obviously progressive.

Tom Bishop

Molten Baths – Error Corrected

PHILADELPHIA

In the November 1955 issue of *Metal Progress* I noticed a serious error in your edited version of my article on "Molten Baths and Mechanisms".

I refer to the section entitled "Uniformity in Temperature" on p. 106 and 107. The last sentence – and the most important one since it sums up the whole paragraph – reads ". . . the maximum deviation at 1000° F. of 25 equally distributed checking points was 70° F." It should have been 7° F. instead of 70°. That error changed the entire meaning of that section. To readers who are not familiar with the temperature distribution characteristics of a salt bath, the 70° F. figure may have appeared correct.

L. B. ROSSEAU
Vice-President, Ajax Electric Co.

Measuring Case Depth – a Correction

In "Correspondence" columns, October 1955 *Metal Progress*, is a description from a British friend giving his method of measuring case depth. L. E. Webb, chief metallurgist of Clark Equipment Co., had at about the same time sent in a very brief note saying that the S.A.E. Handbook contained much information on the same problem discussed by several recent correspondents. The Editor thereupon used two paragraphs to summarize the S.A.E. Recommended Practices, but at the very last wrote "Rockwell C-30", when it should have been "Rockwell C-50". It's not a printer's mistake, this time.

Iron-Aluminum Alloys

SILVER SPRING, MD.

We were very much interested in reading the article in the October 1955 issue of *Metal Progress* entitled "Ductile Iron-Aluminum Alloys", by Eric R. Morgan and Victor F. Zackay of the Scientific Laboratory, Ford Motor Co.

It is gratifying to learn that many of our own results are being confirmed by other investigators. (The principal publications have been in U.S. Naval Ordnance Laboratory Reports No. 2819 of April 1953 and No. 3700 of June 1954, and in *Journal of Applied Physics* for March 1954.) We have felt from the very beginning of our work that the Al-Fe base alloys hold great promise for applications in both the magnetic materials and high-temperature alloy fields, particularly from the standpoint of being able to use plentiful and nonstrategic alloying elements.

We have experienced continued improvements in the room-temperature ductility and workability of Al-Fe base alloys containing higher percentages of Al in combination with additional elements. We have found, for instance, that it is not only possible to hot work an alloy containing 18% Al but also to roll it down to relatively thin sheet and strip. Also that there is a negligible change in oxidation resistance when molybdenum is added to alloys with high Al contents.

Our investigations of the magnetic properties of the Fe-Al-Mo system may be summarized by the following typical values:

Initial permeability (μ20) 7,000
Maximum permeability (μm) 130,000
Coercive force (Hc at Bm 30) 0.012 Oersted

Figure 5 on page 128 of *Metal Progress* for October 1955, showing the stress-rupture properties of two Fe-Al-Ti alloys, confirms the close resemblance between the high-temperature properties of some of the austenitic stainless steels and the ferritic Al-Fe base alloys, indicating further the potential of these materials in the high-temperature alloy field. It would be interesting to know what value for room-temperature ductility Messrs. Morgan and Zackay were able to get on the alloy containing 14% Al and 3% Ti, since it has been our experience, along with others, that there is some change in ductility with the addition of a third element.

JOSEPH F. NACHMAN and W. J. BUEHLER
Metallurgists, Magnetics Division
Naval Ordnance Laboratory

DEARBORN, MICH.

We are pleased to note the new interest in improving the ductility of iron-aluminum alloys. It has been our feeling that high-temperature alloys of wide applicability must possess sufficient ductility for cold forming. It is natural to expect that any ternary addition which leads to increased hot strength will also decrease room-temperature ductility. For this reason the 14-3 Al-Ti alloy, with less than 5% ductility at room temperature, has limited possibilities as an engineering material. Current work indicates that an alloy containing 8 to 9% Al with 2 to 3% Ti does possess sufficient ductility for cold forming. At

the same time such alloys have hot strength and oxidation resistance comparable with austenitic stainless steels.

We wish to emphasize that aluminum contents in the range of 8 to 10% provide adequate oxidation resistance for service temperatures ranging up to 1900° F.

The embrittlement resulting from aluminum in excess of 10% outweighs the advantage of the small increase in hot strength.

V. F. ZACKAY and E. R. MORGAN
Metallurgy Department, Scientific Laboratory
Ford Motor Co.

A Metallurgical Antiquarian

NEW YORK CITY

I wonder how many Americans know about the way my late lamented friend, Nicolas Belaiew, gave an irrefutable solution to a famous conundrum in Russian folk literature, using his unexampled fund of information about ancient ikons and swords – another instance of metallurgical detective work.

Belaiew's solution was based on his studies of the microstructure of "Damascus Blades" (called "boulats" in Russian). In the tenth and eleventh century these were known as "Kharaloujni" swords, and they were used not by the Russians but by their ancient enemies the Polovtzi – nomads even more nomadic and unsettled than the Russians of those all-but-prehistoric times.

Indeed an important discovery of the text of some old legends was made about 200 years ago in which Kharaloujni swords were mentioned frequently. Efforts to date the legend led only to controversy. All the literati and historians disregarded the true meaning of Kharaloujni, and replaced the word by others meaning "menacing", "heavy" or "sharp". Only Belaiew, with his intimate knowledge of Damascus blades, was able to elucidate the matter, when some 35 years ago he called attention to the fact that the "Kharaloujni" swords had originated in ancient Assyria and had been brought by the Polovtzi into Slavonic lands (the future South Russia) no earlier than the tenth or eleventh century.

Thus the legend obviously described some episodes in the incessant war between the Assyrian descendents and the future Russians!

V. A. NEKRASSOFF

Liquid Titanium

CORVALLIS, ORE.

A friend of the undersigned, while traveling on his vacation through the free Republic of San Marino – famous as is Las Vegas for its fancies such as gambling and divorces – bought there some liquid titanium, which he was so

kind as to present me as a souvenir. This new brand (γ) of titanium is green like the eyes of a witch and apparently very tough. It shares with its American counterpart some properties such as that of inflicting furious headaches on careless consumers, but it does not cause, as far as known, any hydrogenitis or omega disease. The hangovers which result from its abuse seem also to be of shorter duration and rather easy to overcome. Its price compares favorably with the American kind. If absorbed with care by the users of titanium sponge it might help them get over some worries.

W. J. KROLL, Consulting Metallurgist

Furnace additions of **ELECTROMET** *silicomanganese give you many advantages . . .*

• **Combination Alloy**—In making steel, silicon and manganese are much more effective deoxidizers in combination than when used separately. ELECTROMET silicomanganese is designed for the simultaneous addition of silicon and manganese in the correct proportion.

• **Fast Solubility**—Because of the concentration of active elements in ELECTROMET silicomanganese, less time is required for solution in molten steel than when equivalent amounts of silicon and manganese are added separately.

• **Savings in Furnace Time**—Because of the low carbon content of silicomanganese, the carbon in the bath need not be reduced so much as would otherwise be necessary. This results in a saving in furnace time.

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Personal Mention

John M. Haniak

In line with the objectives of expanding and strengthening the editorial staff of *Metal Progress*, John M. Haniak has been appointed an assistant editor. He comes to the American Society for Metals with a rather diverse experience in refractories, steelmaking and nonferrous fabrication.

John Haniak graduated from the University of Pittsburgh as a metallurgical engineer in 1948, but his industrial experience started while attending school, and while working as junior engineer with Harbison-Walker Refractories Co. After graduation he joined Carnegie-Illinois division of the United States Steel Corp. as metallurgical observer in process control in the openhearths, rolling mills and forging shops at the Homestead District Works. His work as special assistant in the report on "Dust Emission From the Openhearth" brought him to the attention of the Allegheny County Bureau of Smoke Control, where he worked for two years with operators of industrial and power equipment in the correction of smoke and dust violations.

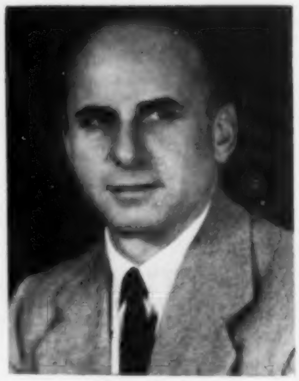
In 1953, Haniak joined the research staff of Olin Mathieson Chemical Corp., East Alton, Ill. as assistant metallurgist and within a year he was named technical assistant to Quality Control Superintendent. Projects with which he was connected included studies of metal drawing lubricants, brass fabrication, aluminum roll-bond techniques and plant standards and specifications. He is especially proud of a directional classification of copper and copper-base alloys according to the amount of plastic work they are able to withstand.

We feel that Haniak's educational and industrial background can be utilized to great advantage in several of the important fields of interest to the A.S.M. members served by their monthly engineering magazine.

Wm. H. Eisenman
Secretary
American Society for Metals

Alvin S. Cohan

Alvin S. Cohan was recently appointed to the newly created position of assistant director of public relations and advertising for Titanium Metals Corp. of America, New York. Mr. Cohan was formerly manager of publications of the American Institute of Mining and Metallurgical Engineers, and editor of the *Journal of Metals*. After graduation from Rensselaer Polytechnic Institute in metallurgical engineering, he spent several years in research, development, and production in powder metallurgy and high-temperature metals. Mr. Cohan has done consulting in technical writing and industrial public relations, and is a contributing author on metal subjects to the Encyclopedia Americana.

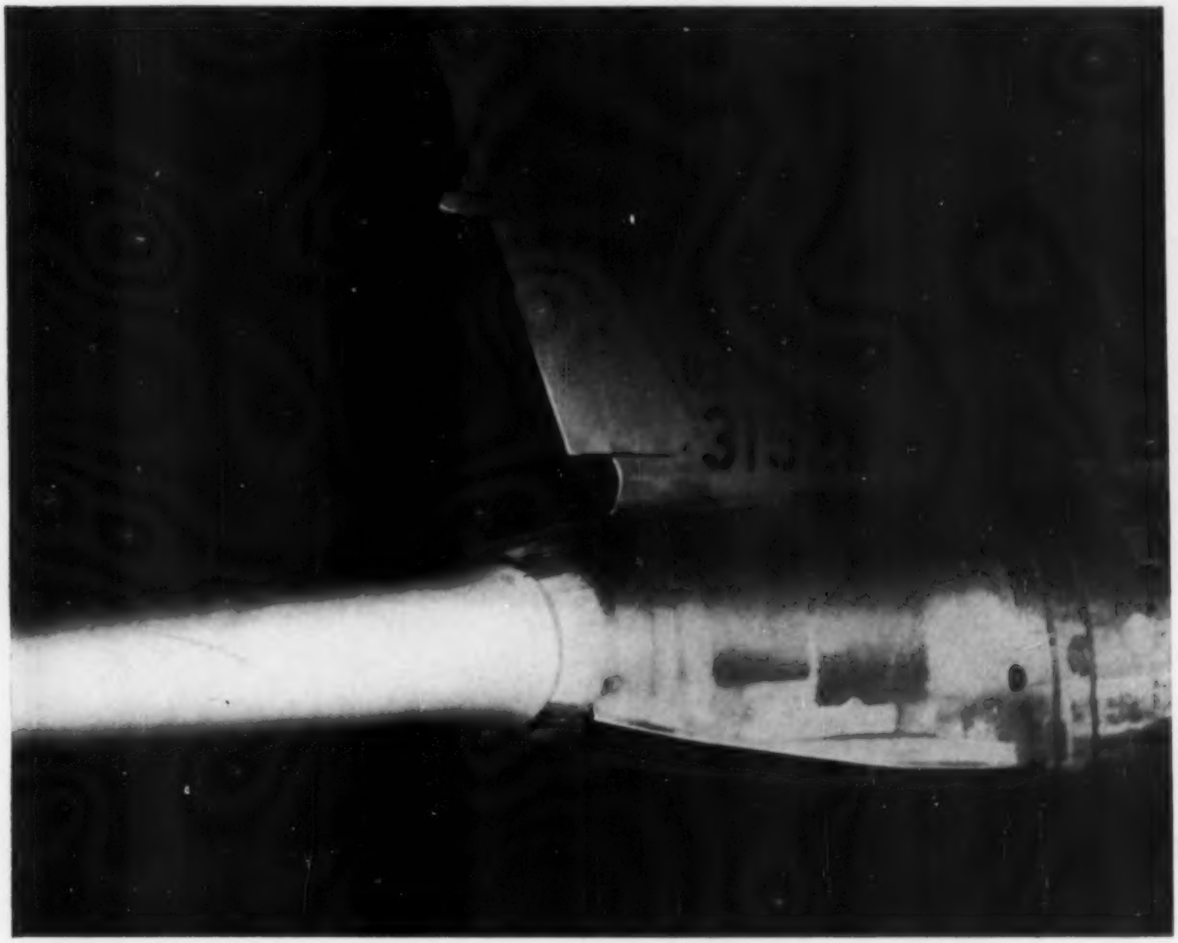


O. T. Marzke

Oscar Theodore Marzke has been appointed director of research of the Naval Research Laboratory, Washington, D. C. Dr. Marzke received his B.Sc. degree in 1929 from Michigan State College, and his D.Sc. in metallurgy in 1932 from Massachusetts Institute of Technology. Prior to joining the Naval Research Laboratory in 1946, Dr. Marzke was a metallurgist with the American Steel and Wire Co., doing both research and plant metallurgical work. His first position at N.R.L. was as superintendent of the metallurgy division, and in 1954 he became the first associate director of research for materials. During the period from 1951 to 1953, he was also head of the Metallurgy Branch of the Office of Naval Research, and was development coordinator for O.N.R. during the first half of 1955.

Dr. Marzke was a member of the Advisory Committee of the Metallurgy Div. at the National Bureau of Standards from 1947 to 1950; Navy member of the Panel on Metals and Minerals of the Research and Development Board of the Department of Defense, 1952 to 1953; and Navy liaison member of the Materials Advisory Board, National Research Council, from 1952 to date. He served as chairman of the Seminar Committee in 1955, and is a member of the Publications Policy Committee.

W. K. Eggert, metallurgical engineer with E. I. du Pont de Nemours & Co., Inc., has been transferred from the Victoria, Tex. plant to the Sabine River works at Orange, Tex.



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Personals . . .

Lew F. Porter, formerly associated with the University of Wisconsin in the department of mining and metallurgical engineering and the engineering experiment station, recently received his doctorate in metallurgical engineering and has joined United States Steel Corp. as a research technologist. Dr. Porter has been assigned to the Brookhaven National Laboratory, Upton, L.I., N.Y., where he is engaged as a guest associate physicist in the solid state physics group studying irradiation effects on metals.

John B. Given was recently appointed associate staff metallurgist in the metallurgical laboratory of International Business Machines Corp., Endicott, N.Y. Mr. Given has been with I.B.M. since 1937, when he was employed as a furnace operator in the heat treating department. He later became a process inspector, and in 1942 was named manager of the heat treating and welding department. In 1945, he was transferred to the engineering laboratory as metallurgical assistant, and in December of 1952 he was assigned to the metallurgical laboratory as associate metallurgist, the position he held until his present appointment.

James D. Glenn was recently elected vice-president of sales, and **Maurice J. Day** was elected vice-president of research and development at Crucible Steel Co. of America, Pittsburgh.

Mr. Glenn had been general manager of sales for Crucible since November 1954. Prior to joining the company in 1948 as general manager of stainless steel sales, Mr. Glenn was vice-president in charge of sales for Eastern Stainless Steel Corp., Baltimore, Md. He was granted leave of absence from Crucible in 1952 to accept a six months' appointment as chief of the stainless steel section, Iron and Steel Division, National Production Authority, Washington, D.C.

Dr. Day is a graduate of Michigan State College, and began his professional career as a metallurgist in 1937 at Gary, Ind., with Carnegie-Illinois Steel Corp., now part of the United States Steel Corp. Subsequently, he served with the corporation as a technical trade representative, physical chemist in research, manager of the alloy division of the Chicago district, and asistant metallurgical engineer for alloy steels. In 1952 he joined the Armour Research Foundation of Illinois Institute of Technology as manager, materials and processes division, and next year became assistant director of the Foundation in charge of program development. Dr. Day became associated with Crucible in 1954 as director of research and development.

Eugene F. Erbin has been appointed metallurgical sales engineer in market and product development for Titanium Metals Corp. of America, New York. Mr. Erbin was formerly attached to the Materials Laboratory, Wright Air Development Center, while on active duty with the U.S. Air Force.

A. G. Channon recently left Kaiser Aluminum and Chemical Corp., where he was employed as a research metallurgist in the physical metallurgy section of the department of metallurgical research, Spokane, Wash., to accept a position as development metallurgist at Hunter Engineering Co., Riverside, Calif.

Roy F. Bourgault is now assistant professor of mechanical engineering at Worcester Polytechnic Institute.

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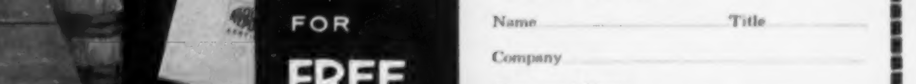

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Personals . . .

Richard A. Nigro ⊕ is now employed in the Omaha, Neb., laboratory of the Union Pacific Railroad.

Joseph J. Buchinski ⊕, formerly project metallurgist at Taylor Instrument Co., Rochester, N.Y., is now an engineer in research and development, general plate division, Metals and Controls Corp., Attleboro, Mass.

Edward D. Weisert ⊕, formerly head of product development section, Haynes Stellite Co. (division of Union Carbide and Carbon Corp.), Kokomo, Ind., is now a research engineer in the metals research laboratories of Union Carbide and Carbon Corp., Niagara Falls, N.Y.

Barry Lichter ⊕ is now a research assistant and candidate for the degree of Sc.D. in the department of metallurgy at Massachusetts Institute of Technology.

Edmund M. Wise ⊕ was recently appointed assistant to the vice-president-manager of the development and research division of the International Nickel Co., Inc., New York. Mr. Wise graduated in metallurgy from the University of Wisconsin in 1919. After service with the Wadsworth Watch Case Co. as metallurgist and director of research, he joined Inco in 1927 to take charge of platinum metals research at the research laboratory in Bayonne, N.J. In 1933 Mr. Wise moved to the New York office to be head of the development and research activities in the fields of platinum metals and applied physics. He is a past chairman of the New York Chapter ⊕, and has contributed importantly to the technical literature. His inventions are covered by more than 50 patents.

R. D. Bardes ⊕ was recently appointed manager of the St. Louis district for Vanadium-Alloys Steel Co., and **Charles A. Lundy** ⊕ has been named to replace **Fred W. Potts** ⊕, who is retiring as district manager of the Cincinnati territory.

Mr. Bardes joined the metallurgical department of Vanadium-Alloys 12 years ago, after graduating from the University of Pittsburgh. In 1945, he was transferred to the sales staff of the St. Louis office. He has served for five years on the St. Louis Chapter ⊕ Executive Committee, holding at various times the posts of secretary and chairman of the membership committee. At present he is in charge of the entertainment committee. As a four-year member of the American Society for Testing Materials Chapter's Executive Committee, Mr. Bardes is currently on the editorial committee, and served as secretary in 1954.

Mr. Lundy, the new Cincinnati district chief, joined Vanadium-Alloys Steel Co. in 1947 as a sales engineer in Detroit. Five years later, he moved to Indianapolis, Ind., to take charge of that office. Mr. Lundy is a native of Syracuse, N.Y., and received his degree from the University of Syracuse.

Ralph G. Wells ⊕ has resigned as supervising technologist with the United States Steel Corp. at the applied research laboratory, Monroeville, Pa., to accept a position in the Engineering Research Institute of the University of Michigan.

Personals . . .

Frederica M. Weitlauf ⊕, formerly technical librarian, Timken Roller Bearing Co., Canton, Ohio, is now librarian, research and development department, Inland Steel Co., East Chicago, Ind.

J. Donald MacQueen ⊕ has been appointed associate staff engineer in the metallurgical laboratory at International Business Machines Corp., Endicott, N.Y. Joining I.B.M. in December 1943, Mr. MacQueen was later assigned as group leader responsible for organic and inorganic finishes and physical testing. In November 1946, he was named associate engineer in the metallurgical laboratory. He graduated from Cornell University in 1926 with a B.Sc. degree in mechanical engineering.

Henry H. Hausner ⊕, formerly manager of atomic energy engineering for Sylvania Electric Products, Inc., Bayside, N.Y., is now general manager, Nuclear Engineering Div., Penn-Texas Corp., New York.

Carl P. Bartels ⊕, vice-president in charge of production for the Mosler Safe Co., Hamilton, Ohio, has been elected to the board of directors. A vice-president of the company since 1951, Mr. Bartels will celebrate his 50th anniversary with the company next June. He was appointed general plant superintendent in 1933.

Charles M. Hammond ⊕ has been awarded the research fellowship which was recently established by the International Nickel Co., Inc. at the University of Michigan. A graduate of the University, Mr. Hammond holds a master's degree in metallurgical engineering and bachelor's degree in chemical and metallurgical engineering. His fellowship work concerns the effect of alloying elements on microstructures and stress-rupture properties of nickel-base alloys.

Jerome W. Kaufman ⊕, formerly metallurgist at the Naval Air Development Center, Johnsville, Pa., is now metallurgical consultant in the mechanical and materials engineering standards group of the engineering products division, Radio Corp. of America, Camden, N.J.

Personals . . .

Thomas A. Henrie recently joined Electro Metallurgical Co.'s Metals Research Laboratories in Niagara Falls, N.Y. as a research chemist in the chemicals research group. Dr. Henrie received a B.Sc. degree from Brigham Young University in 1952, after majoring in chemistry and mathematics. In 1955 he received his Ph.D. in chemistry and metallurgy from the University of Utah, where he studied under a research fellowship sponsored by the Naval Ordnance Test Station at Pasadena, Calif.

George Krauss, Jr. and **Rodney G. Utter** recently joined Superior Tube Co., Norristown, Pa. Mr. Krauss, who has been appointed to the technical division of the metallurgical laboratory, was a 1955 graduate in metallurgical engineering from Lehigh University. Mr. Utter has been assigned to the mechanical development division.

Jay L. Reiss has completed two years' service with the U.S. Army in the Scientific and Professional Program of the Chemical Corps. He is now superintendent of the receiving department for the U.S. Reduction Co. in Toledo, Ohio.

George P. Holman has been appointed senior process development engineer in the manufacturing services of General Electric Co., Schenectady, N.Y. Mr. Holman graduated from Wayne University in 1940 with a B.Sc. degree in chemistry. After working at Detroit Steel Casting Co. for over seven years, during which time he became chief metallurgist, he joined the Chrysler Corp. as a contact metallurgist in its engineering division. In 1951 he was transferred to the Dodge Div. forge plant and was production supervisor for four years. He was named special assignment assistant to the plant manager of Dodge Forge in February of this year.

R. J. Rice, who is in charge of the Texas technical field section, development and research division, for the International Nickel Co., Inc., Houston, has been appointed to the staff of the University of Texas M. D. Anderson Hospital and Tumor Institute as a consultant in analysis of trace elements.

Personals . . .

Beverly W. Duncan has been appointed head of research and development for Misco Precision Casting Co., Whitehall, Mich. Mr. Duncan was formerly chief metallurgist for Alloy Precision Castings Co., Cleveland.

Clayton K. Baer has been appointed manager of the Milwaukee, Wis., sales branch of Crucible Steel Co. of America, after having served for the past year as assistant to the manager of the company's toolsteel sales division. Mr. Baer received a B.Sc. degree in metallurgy from Massachusetts Institute of Technology in 1941, and joined Crucible upon graduation. He was, successively, a metallurgist, supervisor of the metallurgical laboratory, assistant chief metallurgist and chief metallurgist, general supervisor of the metallurgical department for the Sanderson - Halcomb Works, and service engineer in toolsteel sales.

Price B. Burgess, formerly with the engineering research department of Standard Oil Co. of Indiana, Whiting, Ind., is now chief metallurgist at Muncie Malleable Foundry Co., Muncie, Ind.

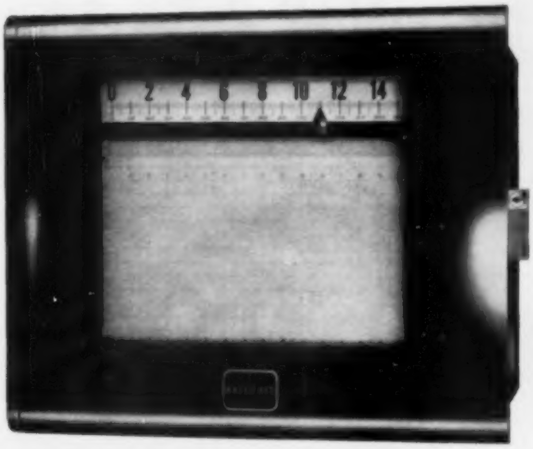
Harold M. Cobb is now chief metallurgist of Clevite Aero Products, Inc., Wallingford, Conn., a subsidiary of the Clevite Corp., Cleveland.

John E. Mosser, who graduated from Pennsylvania State University in metallurgy last June, is employed in the stainless steel section, research laboratory, Allegheny Ludlum Steel Corp., Brackenridge, Pa.

Fred R. Schwartzberg has resigned as metallurgical engineer in the materials development laboratory at Pratt & Whitney Aircraft Corp. to accept a position as principal metallurgist at Battelle Memorial Institute, Columbus, Ohio.

Gilbert R. Semans, formerly research associate at Universal-Cyclops Steel Corp., Bridgeville, Corp., has been appointed assistant director of metallurgy and research for Jessop Steel Co., Washington, Pa. In addition to his new duties at Jessop, Mr. Semans will continue teaching at the University of Pittsburgh's Graduate School of Metallurgy.

WHAT'S NEWS AT BRISTOL . . .



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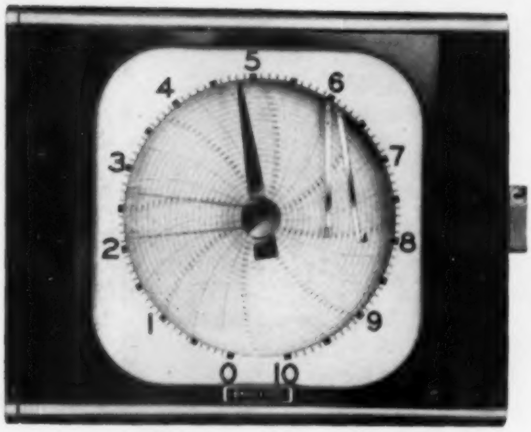

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Digests of Important Articles . . .

Russian High-Temperature Testing Techniques

Digest of "Influence of Boundary Zones, Containing Low-Melting Components, on the Results of High-Temperature Testing of Alloys Under Various Conditions of Deformation", by A. A. Bochvar, M. E. Drits, and E. S. Kadaner, *Izvestiya Akademii Nauk S.S.S.R., Otdelenie Tekhnicheskikh Nauk*, No. 2, 1954, p. 42-45.

Recently there has been considerable work in Russia on the relation between microstructure and high-temperature strength properties. Also, Russian metallurgists have developed two rapid tests of high-temperature strength; the centrifugal method and the long-time hardness test, which have usually correlated well with the conventional tests. However, certain magnesium alloys containing cadmium have failed to show the expected correlation between long-time hardness tests and tensile-type tests of high-temperature strength. The present work was undertaken to determine what effect the grain-boundary microconstituents were exerting in this regard.

The compositions studied are shown in the table. The alloys containing tin and lead were chosen because their microstructures were similar to that of the magnesium-cadmium-manganese alloy. This as-cast structure consisted of a coarse dendritic pattern of solid solution with pronounced intercrystalline and interdendritic segregation of the low-melting component.

The results of long-time hardness tests and tensile-rupture tests are summarized in the table. Although the 60-min. hardness values of the other alloys are about the same as that of alloy M 7, the times-to-rupture at a stress of 6400 psi. are smaller by about a factor of ten. The rupture times at 5000 psi. also show the deleterious effects of additions of cadmium, tin or lead to a magnesium-manganese alloy.

High-Temperature Properties of Several Magnesium Alloys

Alloy	Brinell Hardness Number			Hours to Rupture at 480° F.	
	68° F. 30 Sec.	570° F. 30 Sec.	570° F. 60 Min.	5000 Psi.	6400 Psi.
M 7*; as cast	36.7	17.1	10.0	—	100
Stabilized	38.3	17.2	10.3		
1.5 Mn; as cast	—	—	—	120	—
Stabilized	—	—	—		
10 Cd, 1.5 Mn; as cast	29.7	12.9	8.7	54.0	12.0
Stabilized	25.2	14.3	9.7		
2 Sn, 2 Mn; as cast	24.8	14.8	10.7	27.0	1.3
Stabilized	29.0	13.8	11.6		
1 Pb, 2 Mn; as cast	26.0	12.7	8.8	17.0	2.5
Stabilized	26.4	15.9	11.0		

*Commercial Mg-Mn alloy.

The reason for the difference in behavior is that during a long-time hardness test the load is borne primarily by the matrix of the alloy, while in a tension-type test there is opportunity for flow at the grain boundaries. Thus, long-time hardness tests are adequate for rejecting alloys that are not satisfactory but alloys that pass this type of test should also be subjected to a tension-type test.

A. G. Guy

Low-Alloy Steels to Resist Corrosion

Digest of "The Corrosion Resistance of Low-Alloy Steels", by J. C. Hudson and J. F. Stanners, *Journal* of the Iron and Steel Institute, Vol. 180, July 1955, p. 271-284.

The Corrosion Committee of the British Iron and Steel Institute planned in 1937 a thorough experimental investigation of the effects of low alloy additions on the resistance of steel to atmospheric and sea-water corrosion, and a final report of the results has recently been published. Most of the test specimens were in the form of strip or wire. The former were cut from ⅛-in. strip hot rolled from forged billets derived from laboratory melts of 20 to 100 lb. The wire specimens were cold drawn to 0.128 or 0.064 in. diameter. The 60 heats produced for the investigation were divided among five laboratories. One laboratory used melting stock containing over 0.2% Cu. A commercial Cr-Mo steel, and a few rail steels and cast irons were also tested. The range of compositions included conventional alloying elements such as Cr and Ni to 3.1%, Cu to 1% and Mo to 0.5% with carbon up to 0.5% and Mn to 1.82%; and experimental alloys containing Al to 1.6% and up to 0.5% W, V, Sb, As, Sn, Pb, Bi, Ta, Cb, or Be.

The strip specimens were either furnace-cooled from 1650° F. or quenched from 1650° F. in lead at 840° F., held for 5 min. and cooled in air. The decarburized surfaces were removed mechanically or by pickling. The wire specimens were annealed. Corrosion tests were made in three ways, namely by outdoor atmospheric exposure at Sheffield for up to 5 years, by total immersion in sea water for the same periods, and by an intermittent laboratory spray test. (The latter did not correlate well with results from outdoor exposure or sea water.)

The outdoor exposure was in a severely corrosive industrial atmosphere. The progress of rusting was observed visually and recorded, and finally the strip specimens were derusted chemically and their losses in weight measured. The breaking load of each corroded wire specimen was determined, and the corrosion evaluated by comparison with the breaking load of an unexposed specimen. *(Continued on p. 108)*

Low-Alloy Steels . . .

The immersion tests were made only on strip specimens in a large tank of stagnant sea water, located at the seashore where the water was replenished at high tide. The corrosion was evaluated by derusting and measuring loss in weight.

The results, presented in an extensive table, show good correlation between strip and wire specimens of the various steels exposed to atmospheric corrosion. Conclusions are therefore based on indices arrived at by averaging the results from strip and wire specimens exposed 1, 2, and 5 years. The immersion test results for 2 and 5 years were also averaged to get a "corrosion index" for each steel.

Twelve of the complex low-alloy steels rusted in the atmospheric exposure tests only a third as rapidly as the plain low-carbon steels. Of these 12, 9 contained chromium, 8 copper, and 6 nickel. The only one of the 12 without either copper or nicked contained 1.5% Al, and the only one without either chromium or nickel contained 0.4% Be. Buck's early American work on copper steels, showing the effectiveness of about 0.1% Cu against atmospheric corrosion, is fully confirmed.

Carbon up to 0.4% or 0.5% was found to decrease the atmospheric rusting very little. Manganese up to 1.8% also decreased rusting very little in the absence of copper, and with 0.5% Cu manganese had no effect. Chromium up to 3.1% had a consistently progressive effect in retarding atmospheric rusting, and copper in the chromium steels gave a further improvement. Higher carbon slightly impaired the good effect of chromium. Phosphorus decreased the atmospheric rusting slightly except in the presence of chromium. Silicon was similar both with and without chromium. Aluminum as high as 1.4% greately improved the atmospheric corrosion resistance with and without chromium, but 0.1% Al had almost no effect. Nickel as high as 3% was also very beneficial, its effect being additive to that of chromium and copper. Molybdenum and beryllium likewise improved the resistance to atmospheric corrosion. The other elements not specifically mentioned above did not.

(Continued on p. 110)

Low-Alloy Steels . . .

Tests on a few rail steels gave results in agreement with those obtained on the higher-carbon steel of the laboratory-melted series, except that 0.24% Cu in one rail steel only slightly decreased the rate of rusting.

The few cast irons tested rusted less in the atmosphere than the plain low-carbon steels, but the difference could be accounted for by higher phosphorus, silicon and copper. An iron with 1.18% P rusted more slowly than those with 3.4% Si or 0.84% Cu, the analyses being about normal in other respects.

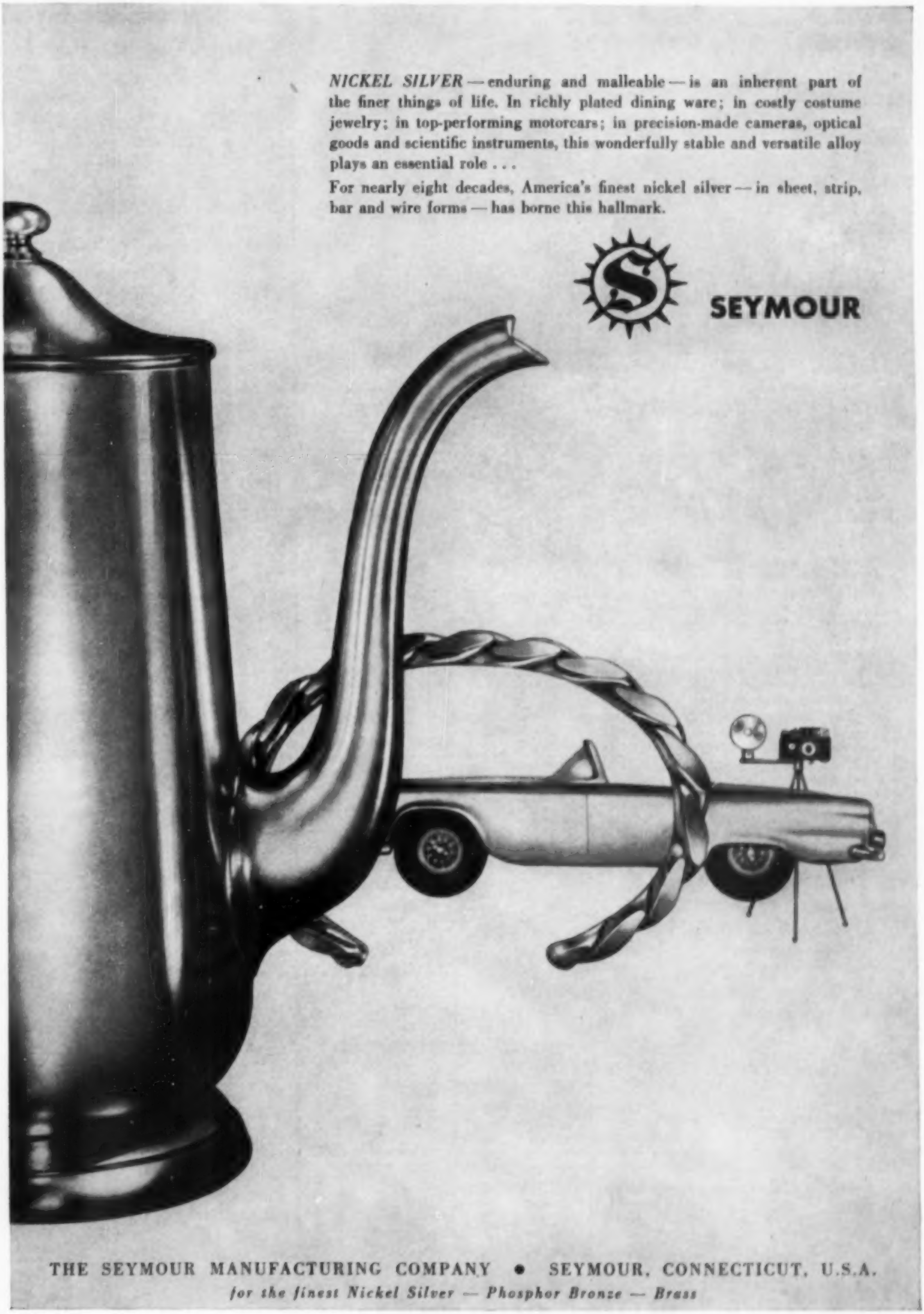
In stagnant sea-water immersion the corroded surfaces were smooth, with pitting on only one specimen. For the plain carbon steels the corrosion rate in sea water decreased slightly in 5 years as compared with 2 years, but for most of the alloy steels the rate per year was higher at 5 years than it was at 2. In sea-water corrosion, improvements due to certain alloy additions were appreciable but somewhat less than in resistance to atmospheric rusting.

The effect of carbon on sea-water corrosion was negligible, the higher-carbon steels corroding a little faster than the lower-carbon. Chromium had a consistently beneficial effect, 2.5 to 3% decreasing the corrosion by half. Aluminum with the chromium gave further improvement. Nickel seemed to be beneficial in 2 years but after 5 years the effect of even 3% Ni was negligible. Beryllium was the only other alloy addition that decreased corrosion in sea water, copper having no effect. None of the alloys seemed to be detrimental in sea water except possibly bismuth.

The cast irons gave about the same results in sea water as the plain carbon steels, the high-phosphorus iron being best, and the malleable iron, which suffered graphitic corrosion, the worst.

It is concluded that low alloy additions can decrease the atmospheric corrosion rate of steel to only a third of the usual rate, chromium, copper and nickel being the most useful. For resistance to sea-water corrosion, chromium is the only alloy of conspicuous value.

GEORGE F. COMSTOCK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Continuing Study Given Nitriding Variables

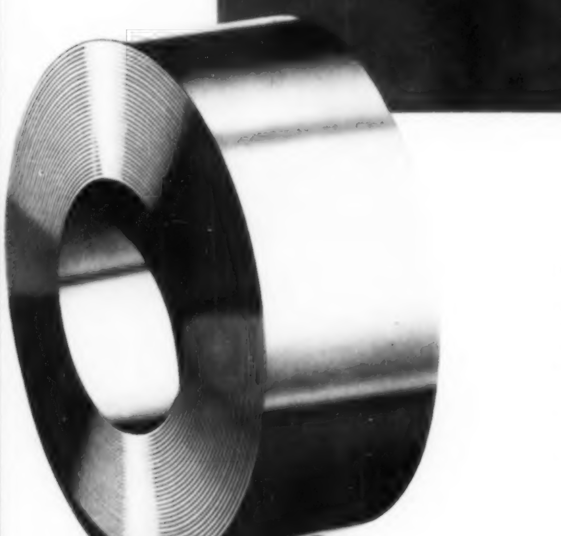
Digest of "A Review of Some Factors Influencing Nitriding Practice", by G. J. Cox, *Journal of Birmingham Metallurgical Society*, Vol. 32, June 1955, p. 187-212.

IN THE 30 years since the advent of nitriding in the U.S., a considerable amount of research, both practical and academic, has been directed toward a more complete understanding of the process, including such details as effect of temperature, time, percentage of ammonia dissociation, pressure, surface conditions, prior heat treatment, cooling rates and de-nitriding. Today, the process is well established, offering the unique advantages of very high surface hardness which is retained at temperatures as high as 1100° F., good wear resistance, high fatigue and creep properties, fairly good corrosion resistance and little risk of distortion in processing.

Early progress was delayed by high costs and uncertain hazards connected with the production of special nitriding steels and the lack of suitable furnace equipment. Further, the beneficial effect of molybdenum in reducing temper brittleness was not widely appreciated.

The original Nitralloy steels, with aluminum an essential constituent, give the greatest hardening effect. However, demands for better fatigue strength and a tougher core led to introduction of other types containing chromium, nickel, molybdenum and vanadium as predominant alloys. The more highly alloyed the steel, the slower is the rate of penetration in nitriding, presumably because of the distortion effect slowing down diffusion rates. Before treating, steels must be oil hardened and fully tempered to a sorbitic structure for a strong, tough core.

Temperature is a major factor in nitriding, the greatest hardening effect being noted at about 930° F. This is dependent somewhat upon the type of steel being treated, the Cr-V analyses, for example, being nitrided at around 860° F. and the stainless steels at 1080° F. At higher temperatures, the hardening effect is lost, the usual explanation being the increased de-nitriding effect of nascent hydrogen present in high concentration. A coagulation of pre-



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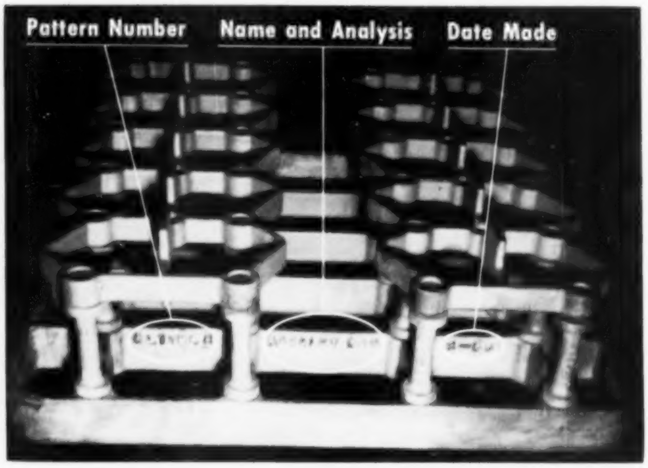

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Nitriding . . .

cipitated nitrides also has been suggested as another reason.

Other disadvantages of higher temperatures include the appearance of a "white layer" on the nitrided surface which usually must be ground off; a tendency toward decarburization, greater growth on nitriding and more danger of distortion occurring.

Maximum hardness commonly is not obtained until exposure of 24 hr. to temperature and ammonia gas, with some cycles running up to 72 hr. Much work has been done in the effort to reduce cycle times. Varying the temperature during the run from low to high, or vice versa, adding a more active nitriding gas to the furnace atmosphere, high-frequency vibration such as through an electric discharge, and the use of solid catalysts in the container have all been tried with varying degrees of success. None has found widespread commercial application.

Conventionally, ammonia dissociation has been regulated at 30% because higher values are assumed to cause excessive de-nitriding and decarburization and increase the explosion hazard with the additional free hydrogen. Many investigators, principally foreign, have disproved this contention, citing instances of improved nitriding practice at ammonia dissociations of 60 to 85%.

Pressure is a variable which has received only minor attention from researchers. One unusual effort in this direction was reported in *Metal Progress* for April 1953. It involved placing parts to be nitrided in pipes along with a sealed capsule of ammonia, then welding ends on the pipes. The containers were passed through a furnace at 930° F.; the solder seal or the capsules melted, releasing ammonia to build up a high pressure. Both time and ammonia consumption were reduced.

With regard to cooling rates, it has been demonstrated that depth-hardness curves are not noticeably affected by different cooling rates; the only significant effect of a slow cool in ammonia atmosphere is the prevention of surface discoloration. However, in one instance, the practice was followed of stopping the gas flow while the charge was still hot

Nitriding . . .

and deliberately allowing air into the retort. The oxide film thus produced was said to improve corrosion resistance and give an attractive finish.

Opinions differ over whether de-nitriding followed by re-nitriding is feasible. Decarburization is believed to accompany de-nitriding so that the original hardness cannot be attained by re-nitriding.

ARTHUR A. ALLEN

Spot Welding Aluminum Alloys

Digest of "Spot Welding of Light Alloys", by J. E. Roberts, *British Welding Journal*, Vol. 2, May 1955, p. 193-199.

IN THE British view, spot welding of aluminum alloys has had an unwarranted bad name. Aircraft manufacturers, for example, have appeared loath to accept the technique despite its extended application among American airframe builders.

Completely satisfactory welds can be assured in production by proper consideration of the materials and equipment involved. Electrical and thermal conductivities of light alloys are much greater than for steel, so welding requires a high current for a short time interval, which means that the current capacity of spot welding machines must be greater than for machines welding corresponding thicknesses of steel. A second factor is the presence on the light alloy surface of an oxide film having high electrical resistance. This can be overcome, where necessary, by suitable chemical treatments that remove the original oxide and leave a thin film of much lower and more uniform resistance.

A combination of chemical cleaning and scratch brushing is advisable. The former should include degreasing, dip in alkaline detergent, rinsing, chemical pickle, another rinse, followed by a flash dip in nitric acid for alloys containing copper. Wire brushing can be done after degreasing, but more consistent results will be obtained if it is carried out after the complete chemical cleaning sequence. Chemically cleaned material which has too high a contact resistance, either through

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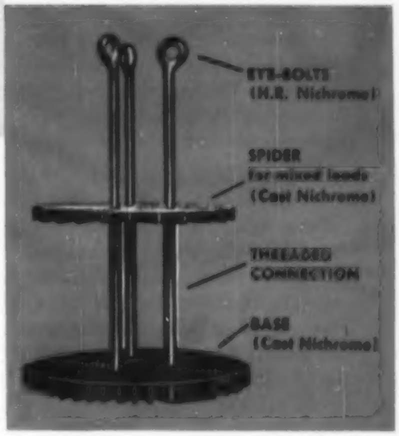

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Nichrome heat-treating fixtures will give you, year in and year out, the lowest obtainable heat-hour costs. For nothing but this high nickel and chromium alloy will come anywhere near the endurance records made under the most severe conditions in plant after plant the country over.

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Spot Welding . . .

incorrect processing or through standing too long after processing, can be conditioned for welding by wire brushing.

The coefficient of expansion of light alloys is greater than that of steels, so there is a greater tendency to form shrinkage cracks in or around the weld nugget during cooling. To overcome this it is necessary to establish the correct current and pressure characteristics in the welder.

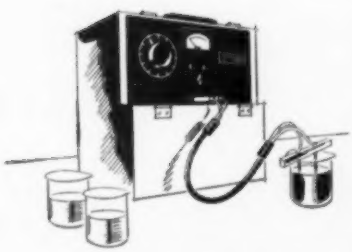
Three principal types of spot welding machines are used in British practice – d.c. stored energy units, single-phase a-c. machines, and frequency converter machines. In all of them the electrode load cycle is of the dual type, wherein the weld is formed with a low electrode pressure. As the weld cools the pressure is rapidly increased to two or three times that employed during welding.

The commonest cause of defects such as shinkage cracks, segregation rings and missing welds is the use of incorrect electrode sizes. Normally, the smaller electrode should be used against the thinner sheet, but frequently the opposite combination is specified to reduce indentation on a thin skin attached to a heavy stiffener. In such combinations, the outer electrode should have a large domed tip rather than a large flat tip, to provide more constant and controllable electrode contact.

The practice of merely replacing rivets with spot welds is shortsighted. While it appears adequate to use ⅛-in. rivets for, say, 14-gage sheets, spot welds in this thickness should be at least 9/32 in. diameter, so wider flanges are necessary. A component should be redesigned before such a change from rivets to welds is made, and it may mean that fewer, but larger, stiffeners will be needed to keep total weight constant. Too often the welding engineer is presented with an unsuitable final design and instructed to weld it. He should be consulted in laying out the original design.

With one notable exception, still on the secret list, no British aircraft has any important use for spot welding. However, manufacturers are watching with interest the expanding usage of spot welding on aircraft in other countries.

A lightweight seven-unit diesel



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Spot Welding . . .

train, built largely of Al-Si-Mg sheet alloys and extensively spot welded, has recently been put in service by the German State Railways. Sheets are 3 and 5 mm. thick, welded on three-phase frequency converter type welding machines.

A recent innovation in the use of Al-Mg alloys (3 to 5% Mg) is found in the Dyna-Panhard 54 motor car. General method of construction is similar to that of a steel body and spot welding is used to a large extent. Special equipment was devised, including portable welding machines with transformers built into the heads to avoid long secondary leads, and also several multiple-electrode welders, believed to be the first of their type for use on light alloys.

A. H. ALLEN

Cracking of Stainless Steel Welds

Digest of "Initial Characteristics of Chromium-Nickel Steel Weld Metals", by J. Heuschkel, *Welding Journal*, Vol. 34, October 1955, p. 484s-504s.

ALTHOUGH austenitic steel weld metal is ductile at room temperature, it is often cracked at elevated temperatures by thermal stress. The cracks may occur during solidification of the weld metal behind the arc crater, or after solidification but near a subsequent arc crater, or during heat treatment, or during service under stress at temperatures above about 1050° F. Extensive cracking in service may be the result of undetected fissures formed earlier. Since low ductility of the weld metal at elevated temperatures is the direct cause of the cracks and a compilation of the high-temperature tensile properties of such metal has not previously been published, a thorough investigation of 15 compositions was undertaken at the Westinghouse Research Laboratory.

The weld metals tested contained 17.1 to 25.9% Cr, 9.2 to 33% Ni, 1.4 to 1.66% Mn, 0.31 to 2.02% Si, 0.04 to 0.16% C, and up to 1.99% Mo, 0.34% Ti, 0.94% Cb, 1.4% W, and 0.085% N. Tensile tests were made at controlled temperatures and strain rates on weld metal deposited with-

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Stainless Welds . . .

out restraint in the form of single-U grooved welds in ⅝ or ¾-in. plate. With only one exception all the welds were free from cracks. The plate was deformed about 10° by each weld. The tensile specimens were machined lengthwise from the weld deposits 2.25 in. long by 0.357 in. diameter. Each kind of weld metal was tested at 6 to 15 temperatures between room temperature (or sometimes – 300° F.) and 2000 or 2200° F., with continuously recorded load-deflection curves. All the deposits were analyzed chemically and examined metallographically, some with an electron microscope. The ferrite contents, which ranged from 0 to 27% before straining, were estimated from Magne-Gage measurements.

All the weld deposits became weaker more or less regularly as the test temperature rose. Most of the alloys also lost ductility as well as strength between 1200 and about 1800 or 2000° F. At that point a minimum in many of the ductility-temperature curves occurred with improved ductility at higher temperatures. The low ductility at about 1800° F., well below the melting point, was believed to be due to weakening of the grain boundaries by a film that was changed or dissolved at higher temperatures. The fully austenitic welds were stronger at high temperatures than those containing ferrite. The present data, however, do not support the belief that ferrite in the weld metal reduces the sensitivity to cracking. The elongation at 1200° F. and at 1800° F. did not increase with the ferrite content at 80° F. The austenitic welds were brittle at 1800° F. and crack-sensitive because the grain matrix is relatively strong so that imposed stresses are concentrated at the grain boundaries, which are contaminated and weak. Although the plain chromium-nickel steel welds that showed some ferrite at 80° F. happened to be less strong and more ductile at 1800° F., no correlation between ferrite content and elongation at 1200 or 1800° F. was exhibited in the charts plotted from data for all compositions.

Weld deposits of Types 321 (18-8 Ti) and 316 (18-8 Mo) had very good ductility (above 21%

elongation) at 2000° F., with higher values at all lower temperatures and no dip in the ductility-temperature curve at 1800° F. Type 347 welds (18-8 Cb) all showed this dip with some elongations as low as 6% at 1800° F.

Silicon and columbium were the most embrittling elements at 1800° F., but no welds with high nickel (above 15%) were ductile at 1800° F. Nickel consistently increased the strength at 1800° F., and chromium decreased it. All welds with more than 16,000 psi. tensile at 1800° F. had less than 12% elongation.

For the best high-temperature ductility and freedom from cracking in this type of weld metal the lowest strength above 1200° F. should be sought by restricting the nickel and columbium contents and adjusting manganese to about 4% (supporting data on Mn will be published later). Raising chromium to decrease strength is inadvisable because of the danger of forming brittle sigma phase. In addition to decreasing the hot strength, the hot ductility should be promoted by decreasing or altering the form of the boundary-weakening elements silicon, carbon, nitrogen, oxygen, sulphur and phosphorus. The Type 321 weld with excellent ductility was the cleanest because of the use of electrodes with the lowest impurity content and an effective argon shield.

Photomicrographs are shown to prove that a weld that was free from microfissures when completed developed local fissuring when strained in tension at 1650° F. The cracks were all approximately normal to the tensile stress at 1800° F. and usually followed grain boundaries. Crack susceptibility in weld metal is thus not necessarily due to the formation of fissures in welding. High-temperature bend tests would evaluate such susceptibility.

The existence of notches between beads or between weld and plate is common in welds and increases the necessity for high ductility. A minimum of 15% elongation at 1800° F. is considered desirable. In both Type 308 and Type 347 weld metals the ratio of notched to unnotched strength is over one at all temperatures up to 2000° F. so that neither is by definition notch-sensitive. But

Stainless Welds . . .

between 1400 and 1800° F. Type 347 welds, with 5.7% elongation, showed a very decided drop in the ratio of notched to unnotched ductility. (The notched elongation was only 0.004 in. in 1.5 in.) Type 308, with 20% elongation, showed at those temperatures its highest ratio of notched to unnotched ductility. Thus notches in Type 308 welds are not so serious.

Solution heat treatment of these high-alloy welds lowers the yield strength and increases ductility, especially at high temperatures, but while heating a weldment to the effective temperature, thermal stress can often produce cracks. Fissures were actually obtained by stressing at 1500 and 1800° F. in the laboratory. Cracking in service at temperatures below that at which minimum ductility exists is explained by assuming that with prolonged stress the temperature for loss of ductility would be lowered.

It is concluded that there is no relation between ferrite content of these austenitic welds and hot ductility, but that fully austenitic welds with stronger matrices cannot be ductile at high temperatures unless the grain boundaries are microscopically clean. Welds having low ductility at 1800° F. are likely to crack not only when made, but also later in service. Welding electrodes and technique should be evaluated on the basis of the deposits between 1500 and 2200° F. instead of at room temperature.

G. F. COMSTOCK

Diffusion in Iron-Chromium Alloys

Digest of "Influence of Chromium on the Self-Diffusion of Iron", by P. L. Gruzin, *Doklady Akademii Nauk S.S.S.R.*, Vol. 100, 1955, p. 65-67.

THE QUESTION of the mechanism by which alloying elements influence the rate of solid-state reactions in steel – and therefore steel hardenability – is of both scientific and practical interest. Measurements of the decrease in rate of decomposition of austenite caused by additions of chromium indicate that these addi-

Diffusion . . .

tions strengthen the binding of the iron atoms and significantly decrease the rate of diffusion of iron in the iron-chromium alloy.

Diffusion rate measurements were made on two steels whose compositions were: 7.90 Cr, 0.03 C, 0.06 Si, 0.21 Mn, 0.22 Ni, 0.024 S, 0.007 P; and 3.98 Cr, 0.17 C, 0.18 Si, 0.24 Mn, 0.15 Ni, 0.22 S, 0.008 P. Homogeneity was obtained by hot working the 11-lb. ingots and then annealing the billets for 30 to 40 hr. at 2000 to 2200° F. Diffusion specimens, $0.2 \times 0.3 \times 1.0$ in., were prepared and then vacuum annealed at 2000 to 2200° F.

The self-diffusion coefficient of iron was determined using Fe^{59} and three to five tests were averaged. At 2190° F. the D values were:

8% Cr alloy	9.0×10^{-11} sq.cm./sec.
4% Cr alloy	15.0×10^{-11}
Pure iron	5×10^{-11}

(The value for pure iron is given for comparison and is consistent both with previous Russian work and with the results of Birchenall and Mehl in this country.) Although the self-diffusion coefficient is higher in the iron-chromium alloys than in pure iron at higher temperatures, at temperatures as low as 1650° F. the presence of 8% chromium lowers the D value of iron by a factor of about ten. This change with temperature occurs because the activation energy, Q, for the 8% chromium alloy is 90,000 cal. per mol compared to 68,000 (74,200 according to Birchenall and Mehl) for pure iron.

The experimentally determined Q value for the 4% chromium alloy was 69,000, but the presence of 0.17% carbon in this alloy modified the effect of the chromium. When a correction was made for the effect of the carbon, the revised Q value was 75,000. Since the latter value seemed more reasonable it was concluded that carbon has the same influence on the self-diffusion of iron in the presence of chromium that it has in chromium-free alloys.

These measurements of self-diffusion of iron in iron-chromium alloys gave support to the view that chromium retards the decomposition of austenite by increasing the binding of the iron atoms and by slowing their diffusion at temperatures below about 2000° F.

A. G. Guy

Extrusion of Aluminum Cable Sheath

Digest of "Experimental Extrusion of Aluminum Cable Sheath at Bell Telephone Laboratories", by G. M. Bouton, J. H. Heiss and G. S. Phipps, *Bell System Technical Journal*, Vol. 34, May 1955, p. 529-561.

EXTRUDED aluminum telephone-cable sheath costs less, is lighter and has greater tensile and creep strength than lead. However, the technique for extruding such protective covering directly over paper-insulated cable core at low temperature to avoid ruining the paper or other organic insulation has yet to be developed to commercial perfection. Laboratory exploration of the process makes the outlook promising.

In the telephone industry, lead has already been supplanted to a major extent by composite sheaths, such as Alpeth or Stalpeth. The former is a thin corrugated aluminum sheath covered with extruded polyethylene-carbon black compound. The overlap seam in the aluminum is sealed with an organic adhesive. Stalpeth consists of a thin corrugated aluminum inner sheath without overlap or seal. Over this is a sheath of corrugated tinned steel sheet with soldered seam. The assembly is covered with extruded polyethylene compound. An all-aluminum sheath would cost less than these composite sheaths.

While the fatigue limit of aluminum at 10^8 cycles is well above that of lead on a stress basis, in aerial service the strains might be similar in lead and aluminum sheaths since their temperature coefficients of expansion are similar and the copper core exerts a controlling effect on both types. Because of the higher modulus of elasticity of aluminum, a given strain results in a much higher stress than in lead. It is known further that temperature fluctuations cause strains in aerial cable sheath considerably above the fatigue endurance limit. Hence, until strain data are collected on sheath in service environments and fatigue tests are conducted at such strains, the field life expectancy of aluminum-sheathed cables will at least be open to question.

Early studies on the plasticity of aluminum sheath indicate that about ten times as much pressure would be

required to extrude 99.99% aluminum, compared to lead with 1% antimony at 510° F. The pressure would be even greater for less pure aluminum. About 50,000 psi. is required to extrude lead cable sheathing alloy through conventional extrusion dies, so the pressure for aluminum in such equipment would be far beyond the strength of available structural materials.

A new type of press was designed which has two pistons operating from opposite ends of the extrusion cylinder. Ratio of bore to stroke was made as large as possible because of pressure loss through friction and shear of aluminum at the cylinder walls. Use of two opposed pistons insured a reasonable amount of material being extruded per stroke. For example, two cylindrical aluminum billets of 2.2 in. diameter and about 3.5 in. long produced about 50 ft. of cable sheath, ½ in. diameter with 0.028-in. wall.

Heat is supplied to the ends of the cylinder through two sets of band elements regulated by a recording controller. Pistons are heated by sliding coil heaters which serve to balance the heat lost by conduction through the pistons and thus tend to provide good temperature distribution along the cylinder wall. The press may be operated either at constant applied pressure or constant extrusion rate through suitable valving and gages.

The opposing operation of the pistons minimizes the bending moment on the tools and also reduces the shear surface within the aluminum as it approaches the extrusion orifice. This design results in far less dissipation of pressure than in conventional single-piston lead presses in which some of the material from the top must flow around the core tube, join and then flow through a highly restricted path to the point of sheath formation.

The shape of the tip of both the die and core tube has an important effect on the quality of the sheath and the extrusion rate. A sharp edge on the die results in high extrusion speeds, but the sheath is neither round nor smooth. Smoothness was improved by varying the radius of the extrusion point, but the sheath was either very much out of round or perhaps flattened in side portions.

Flattening was believed to be the result of distribution of pressure to

Cable Sheath . . .

the top and bottom rather than to the sides of the die and core tube; thus a variable extrusion rate was produced around the annulus. To equalize this pressure the radius at the tip of the die was replaced with a 45° conical section ground to provide a "land" whose length could be varied as required. This land formed the outer sheath gate surface of the annulus, and produced improvement in both smoothness and roundness.

Other details of die and core tube design were found equally important. Increasing the length of the land from 0.020 in. to 0.033 in. gave a reduction of extrusion speed. Decreasing the land from 0.020 in. below about 0.005 in. tended to produce rough, irregular sheath. Increasing the angle of the core tube beyond the 45° angle of the die land resulted in sheath that was rough and out of round. Best results were obtained when the core tube angle was slightly less than the die land angle which was fixed at 45°. This produced a slightly restricting effect as the aluminum approached the final point of wall thickness.

The extrusion temperature must be limited in order to prevent damage to the core wrap paper. A temperature of 620° F. causes only slight discoloration of red and white undried core wrap paper.

In conventional extrusion where continuous lengths of tubing are not required, the practice is to remove the cylinder residue from the press after each extrusion stroke. When a cylindrical billet is placed in the press cylinder, there is a tendency for the billet to become thicker in the middle as pressure is applied at one end. This may effectively seal the cylinder at this point and entrap a fairly large amount of air between this restriction and the old charge material. The condition can be corrected by scoring the billet with four equally spaced longitudinal "V" grooves approximately 0.010 in. wide and deep.

Air entrapment can be minimized further by maintaining the preheating temperature of the billets slightly below that of the residual charge in the cylinder. The end of the billet in contact with the hotter residual charge increases more in diameter than does the cooler portion close to the piston, thus contacting the cylinder walls near the old charge first. As temperature equilibration takes place under pressure, the increased diameter moves outward along the axis of the billet toward the piston, forcing air out of the cylinder.

As might be expected from the double ingot charging procedure, seam welds are present in the sheath, diametrically opposite on a horizontal plane. If considerable dross is present, sharp lines of demarcation along these welds may be observed.

Initial experiments indicated that oil coatings on successive billets decreased the extrusion pressure. However, this practice invariably resulted in poor welds in the sheath and was therefore discontinued. Coatings on the core tube and die, however, improved press operation. Among the materials tested as die and core tube lubricants were Teflon, various silicone greases, mixtures of petroleum jelly and mutton tallow, heavy paraffin-base cylinder oils, copper flashes produced by replacement from copper-bearing solutions, and finally a heat-polymerized oil

Cable Sheath . . .

coating. The latter, far the most effective, was produced by dipping the parts in high-temperature motor oil and then heating in air to an estimated 660° F. by a radiant heater.

If attempts were made to extrude ½-in. diameter sheath, using a press having a cylinder five times the area of the experimental laboratory press, it could be estimated that a pressure increase from 63,000 psi. for the latter to 82,000 psi. for the larger unit would be required for 99.99% pure aluminum. For 99.9% alloy, the increase would be from 77,000 to 101,000 psi.; with 99% alloy from 85,000 to 110,000 psi. These values are well below the 150,000-psi. pressure used in commercial extrusion. Were some of the larger diameters of sheath to be attempted, the extrusion ratio would decrease and result in a correspondingly lower extrusion pressure.

ARTHUR H. ALLEN

Vibration During Casting of Gas Turbine Blades

Digest of "The Application of Sub-Sonic Vibrations During Solidification of Castings, With Particular Reference to a Material for Gas Turbine Blades—'H.R. Crown Max'", by S. Hinchliff and Josiah W. Jones, Report No. 89, College of Aeronautics, Cranfield, England, April 1955, 42 p.

IMPROVEMENTS in mechanical properties by vibration during solidification of a 23-12 Cr-Ni gas turbine blade alloy are significant. A comparison of a normal static casting poured at 2820° F. with one vibrated during solidification at a frequency of 48 cps. (cycles per sec.) and an amplitude of 0.005 in. is shown in the table on p. 136.

The process of vibration yields a casting with smaller and more equiaxed grain structure which may produce properties approaching those of forged metal. Both amplitude and frequency of vibration are contributory factors, the latter being more important.

The alloy studied is known as H.R. Crown Max and is widely employed in construction of gas turbine elements because of its strength at elevated temperatures and good re-

Casting Gas Turbine Blades . . .

sistance to scaling. A typical analysis is: 0.20% C, 0.40 Mn, 1.60 Si, 23 Cr, 11.5 Ni and 3% W. Specific gravity is 7.90. In the heat treated condition, yield stress is 30 tons per sq. in., elongation about 30% and hardness Brinell 220. Both casting and welding properties are excellent.

Foundry sands dependent for their strength upon wet clay are not strong enough to resist vibration, even when dried, and it is doubtful whether oil-bonded core sands could withstand it. Present practice for making molds in precision casting appears to provide the answer and to allow the further advantage of a heated mold so the metal will run into thin sections. The mold is simply a ceramic filler bonded with amine-modified ethyl silicate. The use of ethyl silicate as a binder formerly required close chemical control but with the introduction of the amine-modified type the application has been simplified; hydrolysis and subsequent gellation are accomplished by the addition of industrial methylated spirits.

Properties of Vibrated vs. Static Casting

	STATIC	VIBRATED
Ultimate strength, tons per sq.in.	37.2	43.2
Elastic limit, tons per sq.in.	16	21.5
Elongation, %	33	41
Reduction in area, %	27	36
Balanced impact, ft-lb.	9.6	13
Grain size, grains per sq.in.	3	15

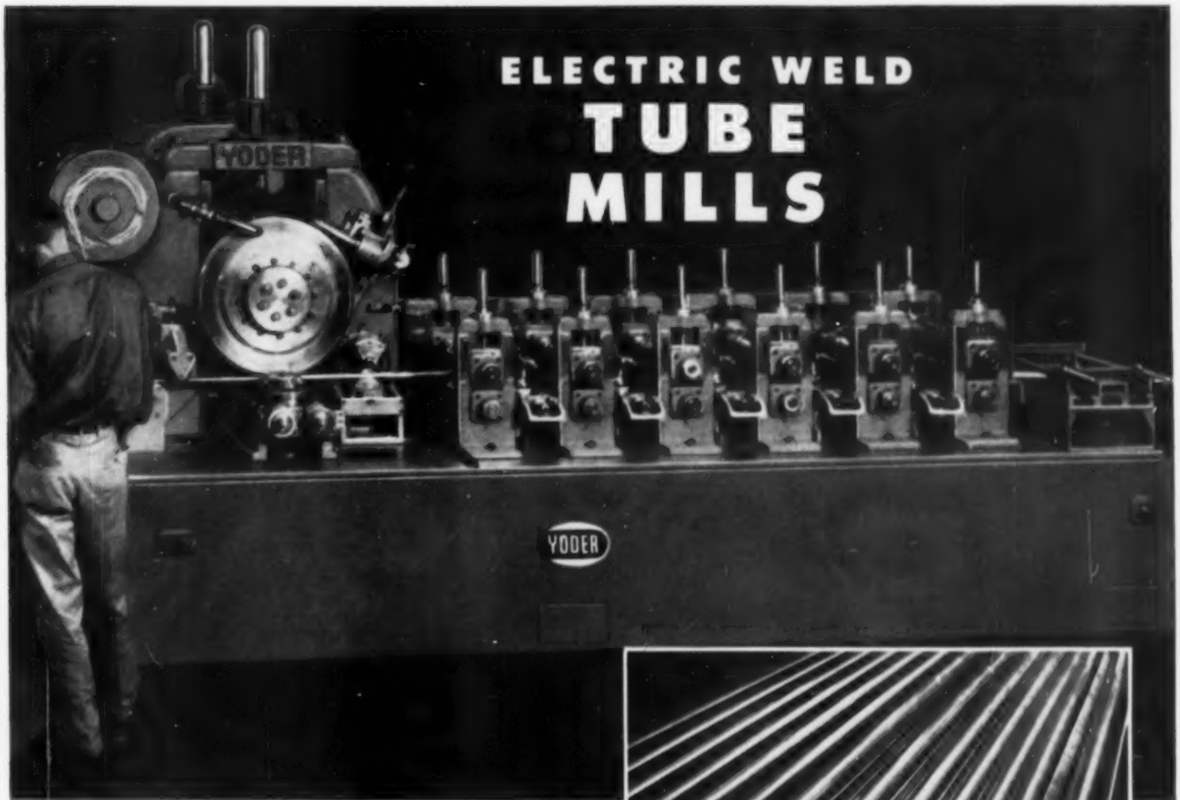
The liquid is an organic silicate with about 40 to 43% SiO_2. When it is fully hydrolyzed a chemical reaction results in the formation of an adhesive gel. When the hydrolyzed liquid is mixed with a ceramic (sillimanite) filler the result is a mold with sufficient green strength for handling. Heating reduces the gel to a finely divided amorphous silica which binds the filler particles. Further heating to high temperature permits intercrystalline growth between the silica and filler, improving the strength and thermal properties of the mold.

It was hoped the sillimanite mold might prove to be semipermanent, but in casting the high-temperature alloy the face slagged with iron oxide rendering it unsuitable for making another cast.

Several different mold washes were tried, but none was entirely satisfactory for repeated use.

Three considerations governed the equipment set-up for vibrating the mold during metal solidification. First, the frequency had to be variable from zero to at least 100 cps. The upper limit is somewhat arbitrary but is dictated to a degree by the power necessary to vibrate the mold, its contents and the holding fixture. Control of vibration amplitude was also important, at least in maintaining a constant amplitude for a given series of tests. Thirdly, mode of vibration had to be approximately sinusoidal and vertical.

A carbon-arc furnace was used to melt the alloy in a crucible with closed-in top having apertures for



The photo shows the tube forming mill and welder of a complete Yoder mill recently installed for an Italian customer. Although it looks very much like a standard Yoder mill, it embodies special mechanical and electrical innovations designed for *tube production at speeds up to 350 fpm*—from 200 to 300% faster than heretofore considered practical by the resistance-weld process.

This is just one example of the many new things introduced by Yoder in pipe and tube making equipment, to meet widely varying production needs. Other recent Yoder developments are induction weld mills for making steel as well as non-ferrous pipe and tubing, at speeds never before approached by this process, and adding greatly to its recognized economic advantages.

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Turbine Blades . . .

feeding, pouring and insertion of the carbon electrodes. The vibrator and mold were positioned at the side of the furnace, with the tilting trunnion of the furnace moved to the outside adjacent to the mold so that as the furnace was rotated the pouring lip came into position immediately over the mold runner.

Temperature of liquid metal, rate of pouring and temperature of the mold were all determined to be critical factors. A minimum mold temperature of 1830° F. was necessary at the moment of pouring for best results. In actual tests, pouring temperatures varied from 2630 to 2880° F. At the higher temperatures, the improvement in mechanical properties induced by the vibration was most apparent.

It is worthy of note that the improved tensile strength, around 16% at frequency of 48 cps. and amplitude of 0.005 in., is not accompanied by loss of ductility or impact value, the latter two increasing 26% and 20%, respectively, over nonvibrated castings. ARTHUR H. ALLEN

Corrosion of "Tin Cans"

Digest of "Corrosion of Metal Containers", by R. K. Sanders, *Corrosion Technology*, Vol. 2, August 1955, p. 238-242.

TIN PLATE is the most widely used material for metal containers or cans although both uncoated mild steel ("black-plate") and aluminum are also used.

The older, hot dipped type of tin plate is made by passing steel sheets through molten tin. The newer, electrolytic type is produced by electroplating tin from an aqueous solution and subsequently heating the thin coating to fusion. The thinnest serviceable coating that can be made by hot dipping weighs about 14 oz. per 31,360 sq.in. of sheet coated on both sides (or "14 oz. per base box"), while useful electrolytic plate may have a coating less than a third as thick (4 oz. per base box). The thinner tin coatings are more porous and therefore less resistant to rusting. Electrolytic tin plate even with the tin removed is more resistant to acid attack than normal sheet steel, but this property has been inversely cor-

Tin Cans . . .

related with the shelf life of certain canned fruits. The solubility of the tin coating also differs according to whether the sheets were hot dipped or electrolytic. Hot dipped coatings carry a film of palm oil mixed with fatty-acid salts, while the surface of electrolytic coatings is tin oxide with cotton seed oil.

Hot dipped 16-oz. coatings prevent rust in most applications; 8-oz. electrolytic coatings require care in storage; and 4-oz. coatings must be lacquered to prevent rusting. Moisture is required for rusting so it can be prevented by complete dryness and cleanness. Vapor-phase inhibitors are of little value, but dichromate inhibitors are useful additions to cooling water in canning to prevent external rusting of cans. A very thin film of oil applied before processing also helps prevent rust.

The inside of tin cans usually does not rust because the atmosphere above the contents contains insufficient oxygen. In special instances where internal rusting above the contents occurs, the rust can be dissolved by inverting the cans and no more rust can form inside because the oxygen will have been exhausted. Lacquering is useful to prevent rusting of tin cans used for products other than processed foods.

The interiors of meat cans may be discolored by sulphur compounds reacting to form either tin or iron sulphide. Staining due to tin sulphide is not serious and can be prevented by lacquering. Iron sulphide stain, however, is black and adheres to the contents of the can. Lacquers pigmented with zinc oxide may help to prevent this type of corrosion, but nonreactive lacquers may intensify it.

Canned fish packed with acid sauce may generate hydrogen in the cans if the tin is too thin. Fish packed in oil or brine may attack the tin because of the presence of trimethylamine oxide.

Milk does not corrode tin plate, except for electrolytic plate finished anodically. Where the anodic oxide film is damaged in making the can, milk may etch and discolor such areas during processing.

In tin-plate containers used for certain other products more corrosive than processed foods, elaborate systems of lacquers or wax protective coatings may be necessary to prevent perforation. If something in the product tends to strip the tin from the can even when lacquered, the product must be changed, or a corrosion inhibitor added.

Uncoated steel sheets are called "black plate" because the surface formerly was always oxidized, although they are now supplied with a clean bright surface. They corrode readily and cannot be soldered as easily as tin plate. By using multiple coats of scratchproof and flexible lacquers, however, they can be used for containers for almost any product for which tin plate is suitable although the shelf life is shorter. Much black plate was so used in England during the war and rusting often occurred in irregular thread-like patterns under the lacquer. Bonderizing the steel before lacquering prevented this defect.

Pure aluminum and the 1.25% Mn

Tin Cans . . .

alloy have been used for cans to replace tin plate. They have excellent drawing and extrusion properties but are more expensive, weaker and difficult to solder. Corrosion is more likely to result in pitting and perforation in aluminum cans than in tin cans.

Cans made entirely from aluminum have been used extensively in Norway. They are practical for many vegetable and marine products if made from anodized strip coated with phenolic resin lacquer. Cans having tin-plate bodies and aluminum ends, even though lacquered, have not been satisfactory because of galvanic corrosion. Anodic or acid attack of the aluminum produced perforations, and alkali at the cathodic tin plate caused stripping of the lacquer.

G. F. Comstock

Effect of Martensite on Stress-Corrosion Cracking

Digest of "The Effect of Martensite on Sulphide Stress-Corrosion Cracking" by M. F. Baldy and R. C. Bowden, Jr., *Corrosion*, Vol. 11, October 1955, p. 19-24.

Many investigations of rapid failures of steel in contact with oil from wells giving off H_2O and CO_2 have shown that the failures were due to stress-corrosion. A steel commonly used for high-strength tubing for oil wells that is subject to such failures is medium-carbon manganese-molybdenum steel (A.P.I. Grade N-80). Since it contains some martensite in order to meet the specified minimum yield strength of 80,000 psi., the effect of the martensite on stress-corrosion cracking was investigated by the National Tube Div. Research Laboratory of the U.S. Steel Corp.

Test specimens 10 in. long and 0.225 in. square were cut from the 0.446-in. walls of steel tubes containing 0.37 to 0.42% C, 1.45 to 1.65% Mn, 0.16 to 0.18% Mo, and less than 0.025% P or S. The bars were annealed at 1475° F. for 20 min. plus 2 hr. at 1250° F., then hardened by quenching from temperatures between 1500 and 1170° F. to give structures containing from 100% to nearly zero martensite. The Rockwell

Tool Steel Topics

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If you would like to borrow a print, write to Publications Department, Room 1004, Bethlehem Steel Company, Bethlehem, Pa., selecting a showing date as far in advance as possible.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Multiple Tools Improve Hot-Work Tool Life

All hot-work tools are subject to heat-checking, a type of surface-deterioration consisting of shallow cracks, usually in network form, which lengthen and enlarge gradually during service. The cracks stem from the repeated thermal stress set up each time the tool is used. During use, portions of the tool surface are heated rapidly by contact with the work, causing expansion; subsequently natural cooling, or some type of forced cooling, causes contraction. Repeated cycles of expansion and contraction produce stresses which lead eventually to heat-check cracks which shorten tool life.

If multiple tools are used alternately, the severity of thermal stress in each operation is decreased, thus retarding heat-checking, and lengthening tool life. A typical example is in hot-piercing punches. Often as many as six punches are provided, and used alternately in a rotating fixture which permits rapid placing and removal of the tools. The life of each tool is often doubled in this manner. However, wherever multiple hot-work tools are used, some degree of improvement in tool life may be expected.

Martensite . . .

hardness was found to increase almost linearly from C-20 with 10% martensite to nearly C-60 at 100%. The heat treated specimens were machined to 0.2 in. square and fastened in pairs on straining brackets, each consisting of a heavy steel slab with a $4 \times 4 \times$ ¼-in. glass plate lying on it. The 10-in. specimens were laid across the glass plate and their ends were fastened to the slab with insulated bolts. Thus the 4-in. length over the glass was bent in an upward curve. The stress in the specimens was determined by measuring the deflection above the glass at the center. These stresses were adjusted to 1.4 to 96.8% of the yield strength as determined on heat treated specimens.

The assemblies were immersed at room temperature in water saturated with H_2S and CO_2 until the test was terminated by failure, or by removal for microscopic examination. The specimens and tanks were cleaned once a week. In most of the tests air was excluded from the tanks to decrease general corrosion.

All specimens having hardness of C-30 or less, indicating not over 33% martensite, did not fail. All those with hardness of C-50 or more, indicating 75% martensite, failed even at the lowest stresses. In the intermediate range between 33 and 75% martensite, failure depended on the applied stress. Stresses of less than 25% of the yield strength did not cause failure and those above 50% of the yield strength did cause failure. These results were independent of corrosion rate or steel composition within the range noted above.

The specimens with less than 33% martensite became pitted by corrosion during the tests. Specimens that contained more martensite and either did not fail or failed slowly showed numerous small transgranular cracks, extending preferentially through the martensite, sometimes from corrosion pits. In specimens that cracked quickly, no corrosion pits or secondary cracks were found.

When martensite is present in a continuous network, this steel is susceptible to sulphide stress-corrosion cracking. Further work is planned to discover a way to process this steel so as to eliminate such susceptibility.

G. F. Comstock

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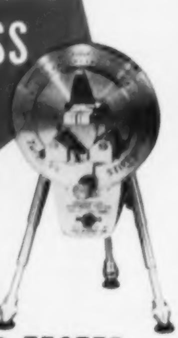

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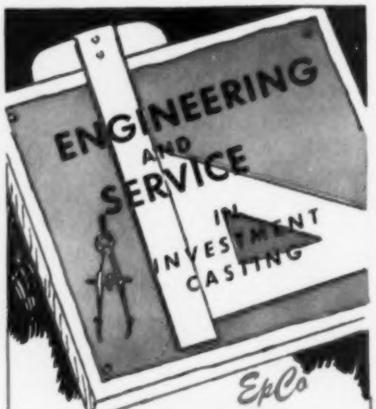

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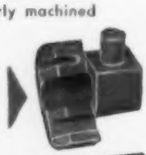

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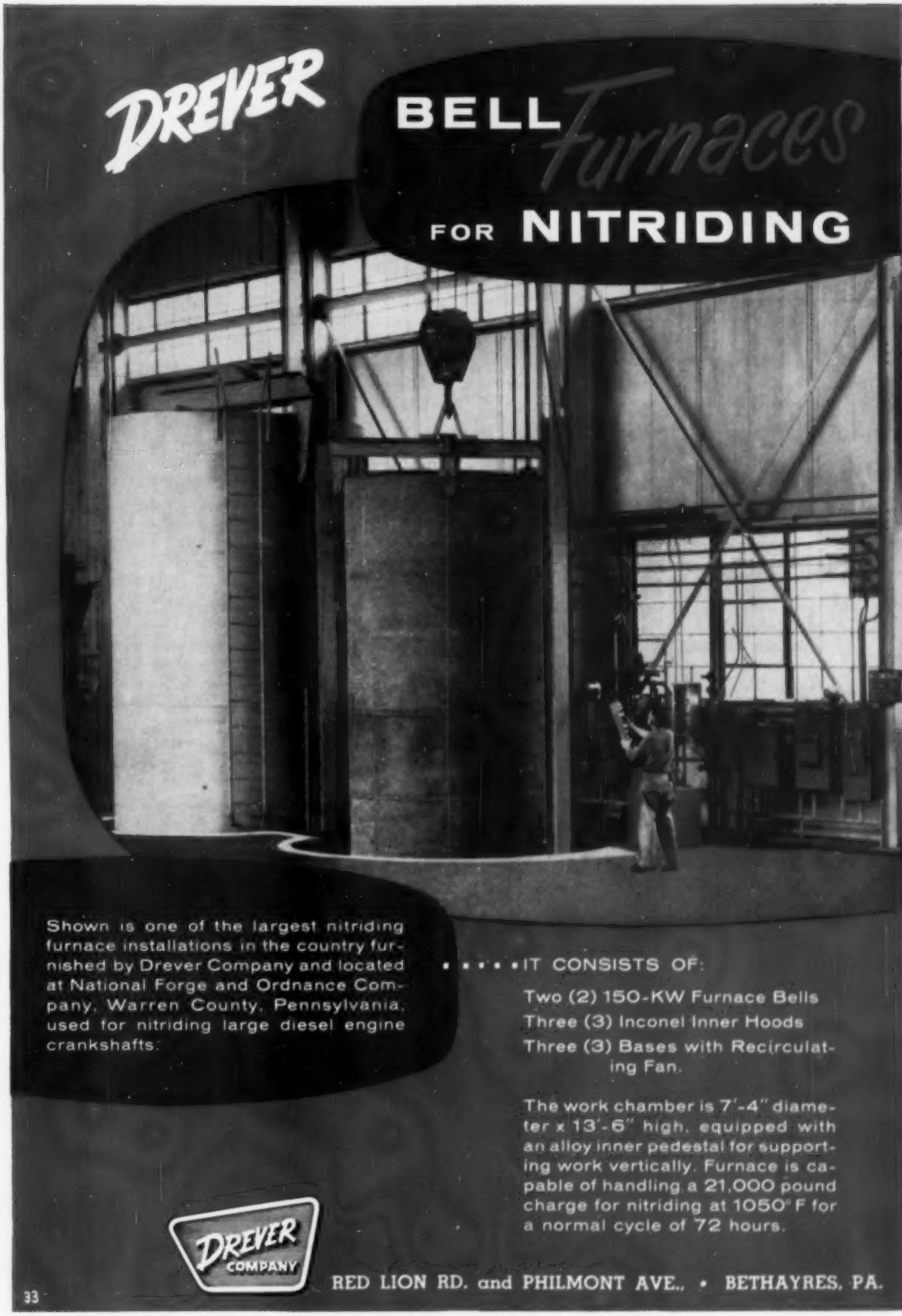
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Corrosion of Coated Steel in Contact With Al

Digest of "Metal Coatings on Steel in Contact With Aluminum Alloys; Some Comparative Tests", by S. C. Britton and R. W. deV. Stacpoole, *Metallurgia*, Vol. 52, August 1955, p. 64-70.

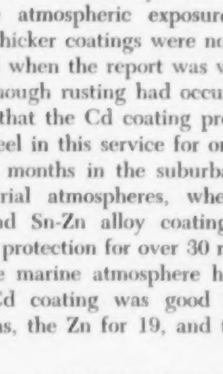
Many aluminum alloys resist atmospheric corrosion well enough to be used for outdoor structures without painting, but steel bolts and screws in contact with the aluminum require protection. Extensive tests of three metallic coatings that can be used on steel parts in contact with aluminum structures outdoors have been reported recently by the Tin Research Institute in England.

The coatings studied were cadmium, zinc and a tin alloy containing 20% Zn, all applied by electroplating as coatings 0.0003 to 0.0007 in. thick. Thicker coatings could not be used on bolts without impairing the fit of nuts, and preliminary tests of thinner coatings showed that they did not last very long. Coatings applied before forming threads did not provide adequate protection. The coatings were applied to ordinary steel setscrews 1¼ in. long and 3/16 in. in diameter, with the threads cut 0.0005 in. undersize, and having one washer and a nut. For outdoor tests these screws were fastened through ¼-in. holes in aluminum alloy sheets 0.048 or 0.064 in. thick, seven screws being placed at least 2 in. apart in a 8×12-in. sheet. Five aluminum alloys were used, No. 1 being commercially pure; No. 6 containing 5% Mg; No. 10 being a heat treated alloy containing Mg, Si and Mn; No. 15 S containing 4% Cu with Mg, Si and Mn; and No. 15 C being the same as 15 S except that it was clad with pure aluminum.

Samples were exposed to atmospheric corrosion at three sites, suburban, industrial and marine, the panels being held at a 45° angle by porcelain insulators. Other samples were intermittently immersed in the sea. Smaller samples (3×4 in.) were subjected in the laboratory to salt spray tests, sea-water immersion, condensation of moisture without direct weathering, and electrode potential and current measurements between the two materials.

In preliminary tests with coatings only 0.00025 in. thick the Sn-Zn alloy coating prevented rusting of the screws and nuts much better than the Zn or Cd coatings in the industrial atmospheric or intermittent immersion tests, but the coatings were too thin for satisfactory service.

The atmospheric exposure tests with thicker coatings were not completed when the report was written, but enough rusting had occurred to show that the Cd coating protected the steel in this service for only five or six months in the suburban and industrial atmospheres, where the Zn and Sn-Zn alloy coatings provided protection for over 30 months. In the marine atmosphere however the Cd coating was good for 34 months, the Zn for 19, and the Sn-



Coated Steel . . .

Zn for 22 months. All five aluminum alloys acted about the same, except that No. 15 S caused the coated screws to rust first. At first the Zn-plated and Cd-plated screws protected the Al sheets from corrosion, but later when the Cd or Zn coatings had failed there was more rapid corrosion of the adjacent Al. For protecting the Al sheets, the Sn-Zn coating on the steel screws is considered superior, except in marine atmospheres.

The Zn-coated screws rusted rapidly in the samples submitted to intermittent immersion in the sea and the Al sheets near these screws were also badly attacked. The Cd coatings were in fairly good condition after 21 months, with the Al nearby only slightly attacked. The Sn-Zn coatings also lasted fairly well, but the adjacent Al was corroded rather severely. The Al alloys were not attacked equally, No. 10 being perhaps the worst near the screws, and No. 6 the best in general.

The condensation test results could not be evaluated accurately because of corrosion products hiding the Al near the screws, but the Cd-plated screws definitely rusted most rapidly. The Sn-Zn coatings acquired a light rust stain early in the test, especially in contact with Al alloy 15 S which was slightly corroded near these screws.

In the salt spray tests the Zn coatings failed in 40 to 80 days, the Cd coatings began to fail in 120 days, and the Sn-Zn coatings, although specked with rust after 99 days, did not fail in 326 days and the nuts could then be unscrewed. By that time the Zn-coated nuts were rusted fast, and the Cd-coated nuts were very difficult to remove. The Al alloy sheets were all badly attacked near the Zn-plated screws.

Immersion in sea water in the laboratory produced some local corrosion of the Al alloy before rusting of the plated screws, possibly due to protection of the steel by scale. When the samples were cleaned after 80 weeks, the Zn coatings were found to have been replaced by scale and the Cd coatings had also been removed, but the Sn-Zn coatings, except for a few that rusted locally in a few weeks, were in good condition. *(Continued on p. 158)*

Coated Steel . . .

Electrode potentials of single specimens of the Al alloys and of plated steel with coatings 0.001 in. thick were measured in a 3% NaCl solution at 30° C. (86° F.) with reference to a silver/silver-chloride electrode. All the potentials were negative, the value for Zn-coated steel being next to the largest (– 1027 mv.) and that for Cd-coated steel among the smallest (– 740). The steel with a Sn-Zn alloy coating at first had a potential slightly higher than that of the Zn-coated steel, but in 4 days it decreased to a small value (– 670). The potentials of the Al alloys varied from – 946 mv. for No. 10 to – 660 for No. 15 S.

Measurements of the current flowing in couples formed of an Al alloy and a plated steel rod, immersed in 3% NaCl solution, gave results different from the potential measurements but more in accordance with the performance of the bimetallic assemblies. These currents were generally not more than 10 micro-amp. Whereas bare steel was always strongly cathodic toward most of the Al alloys, the plated steels were initially anodic, those with Zn or Sn-Zn coatings becoming slightly cathodic after several days. Alloy 15 S however was exceptional; all the steels except that plated with the Sn-Zn coating remained anodic toward it.

All the coatings 0.0005 in. thick had a disappointingly short life compared to that of aluminum structures outdoors.

The cadium coating was best in marine environments, but worst in inland environments. The Sn-Zn coating was nearly as good as the best in both environments and is most generally useful. It does not protect adjacent Al sheets completely but defers for a long time the accelerated corrosion that follows the complete failure of a Cd or Zn coating on a steel screw in contact with the Al. Hygroscopic corrosion products form less copiously on the Sn-Zn alloy than on Zn or Cd. The Sn-Zn coatings have been found useful for protecting steel against atmospheric corrosion and this usefulness is now extended to include contact with aluminum.

G. F. COMSTOCK

Decomposition of Metastable Structures by Plastic Deformation

Digest of "Effect of the Decomposition of a Solid Solution Produced by Plastic Deformation on the Mechanical Properties of an Aluminum-Copper Alloy", by V. A. Pavlov, *Doklady Akademii Nauk S.S.S.R.*, Vol. 95, 1954, p. 1201 to 1203.

THE DEFORMATION of a metastable solid solution in a temperature range where plastic deformation causes the solid solution to decompose is known to cause such phenomena as "toothed" effects in a stress-strain curve, anomalous relations between deformation resistance and speed of loading, and an increase in deformation resistance. On the other hand, if an alloy is deformed in a temperature range in which the solid solution decomposes rapidly in the absence of plastic deformation, then the deformation resistance decreases. These effects indicate a mutual influence between plastic deformation and diffusion.

In the present work a study was made of the variation with temperature of the mechanical properties of 99.97% aluminum and of an aluminum alloy containing 1.3% copper. This alloy undergoes decomposition of its solid solution in a portion of the temperature range used, −300 to +750° F. The test specimens were wires 0.077 in. in diameter and 1.2 in. in gage length. Alloy specimens were quenched immediately before being tension tested.

In the range from 70 to 390° F. the stress-strain curve of the alloy was "toothed", and at 210° F. there was a yield plateau as well. These effects indicated active decomposition of the solid solution. The deformation resistance of the pure aluminum fell rather smoothly with increasing temperature from 25,000 psi. at −300° F. to 1500 psi. at 750° F. The corresponding curve for the 1.3% copper alloy lay uniformly about 3000 psi. above that for aluminum from −300 to −100° F. At the latter temperature, however, its deformation resistance dropped off slowly up to 210° F., at which temperature the value was 15,000 psi., compared to 8000 for pure aluminum. Above 210° F. the alloy weakened rapidly and at 750° F. it was

Plastic Deformation . . .

only slightly stronger than the pure aluminum.

The variation of uniform elongation with temperature followed a similar pattern, with the aluminum dropping smoothly from 42% at −100° F. to 9% at 750° F. The alloy again showed a break in its curve in the −100 to 210° F. range, with the value at 210° F., 33%, higher than that at −100° F., 30%. The work of deformation was the same for both materials except in the range from about 0 to 300° F., where the value for the alloy was higher by a maximum of 25 cal. per mol. The work of deformation decreased from 175 cal. per mol at −300° F. to 5 at 750° F.

The behavior of the 1.3% copper alloy was attributed to diffusion processes occurring during the formation and precipitation of the new phase in the nonuniformly stressed lattice. The presence of nonuniform stresses is known to facilitate diffusion at low temperatures.

A. G. GUY

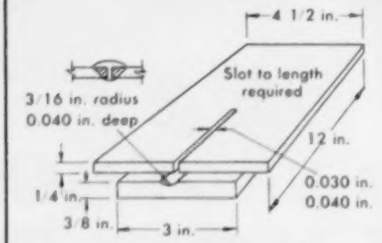
Hot Cracking Test for Aluminum Alloy Welds

Digest of "Fusion Welding of Aluminum Alloys, Part VI", by W. G. Hull, D. F. Adams and H. E. Dixon, *British Welding Journal*, Vol. 2, January 1955, p. 32-36.

THE EVALUATION of crack susceptibility of weld metal in a simple test is of major importance in the selection of new filler materials and electrodes for welding of the Al-Mg-Si type aluminum alloys such as H.10 (1.0 Si, 1.0 Mg, 1.0 Mn). Simplicity in form, preparation and testing procedure is essential. The plate thickness, joint design, and welding technique selected must be similar to those experienced in practice. The restraint should be provided by the test piece rather than by special jigging to avoid the possible influence of clamp geometry and variations in clamping pressure on the thermal cycle. Dilutions of 70 to 80% should be produced to represent the most adverse conditions in practice.

In the test finally adopted, a solid rectangular plate was used which has an open slot machined or sawed

Hot Cracking Test . . .



Butt Weld Cracking Test Specimen for Metal-Arc Electrodes. Shaded area of fused plate shown in inset should be 70 to 80% of the total weld bead area

from one edge along the center line as shown in the sketch above. The severity of the test varies inversely as the length of the slot. The test was calibrated in terms of existing electrodes of known cracking behavior at high dilution. The standards selected for this purpose were 5% Si aluminum alloy, known to be crack sensitive at high dilution, and 15% Si alloy, reported satisfactory.

The test consists of laying a weld along the slot in an H. 10 alloy plate with a 0.192-in. diameter electrode, starting from the edge of the plate. Welding is completed in a single pass at a welding speed of 15 in. per min., using a welding current of 230 to 250 amp. for full penetration. One electrode is used for each test, providing a weld of about 5½ in. After removing the slag, the weld is examined for hot cracks visually and radiographically. When cracking occurs it is normally located in the weld bead along the center line. Crater cracks are not considered as part of the test.

Tests with the 5% Si and 10% Si electrodes over a range of slot lengths indicate that a relatively sharp transition in the cracking behavior occurs at particular slot lengths. Welds made with the 5% Si electrode crack at slots up to 7 in. in length but are crack-free at slots of 8 to 11 in. The critical slot length for the 10% Si electrodes is 6 in. The minimum slot length at which crack-free welds are produced is termed the cracking index for the electrode.

The test can be used successfully to investigate the cracking tendencies of new electrodes and provides a reliable indication of the behavior of weld metal in production.

(Continued on p. 166)

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Hot Cracking Test . . .

It is possible that the principles of the test can be applied to provide a cracking test for welds made by other processes such as the inert-gas-shielded tungsten-arc and inert-gas-shielded consumable-electrode processes. The degree of dilution, which determines the weld metal composition, can be varied by the width of the slot or the dimension of the groove.

PETER PATRIARCA

Failures of Forged Turbine Blades

Digest of "Behavior of Forged S-816 Turbine Blades in Steady-State Operation of J-33-9 Turbojet Engine With Stress-Rupture and Metallographic Evaluations" by F. B. Garrett, C. A. Gyorgak, and J. W. Weeton, N.A.C.A. Research Memorandum E 52 L 17, February 1953, 29 p.

IN AN ATTEMPT to determine the reason for comparatively early failures of turbine blades in normal service in a turbojet engine, 46 commercial forged blades of S-816 alloy were carefully examined before and after such service. The forged blades were quenched from 2150° F. and aged 16 hr. at 1400° F. They were installed in a J-33-9 engine which was operated about 16 hr. a day at 11,500 rpm. until all the blades had failed. In this operation a part of each blade was stressed to 21,500 psi. at 1500° F. The progressive deformation of three blades was measured between periods of operation.

Failures were classified visually as due to (*a*) stress at high temperature, indicated by an irregular granular surface at the origin; (*b*) fatigue, where the surface was smooth at the origin; or (*c*) a combination of (*a*) followed by (*b*), 80% of the failures being in this category. A few stress-rupture tests were made on specimens cut from similar blades, and some of the failed blades were examined metallographically.

Whereas in a previous investigation of forged S-816 blades produced several years earlier the best service life in similar operation was 78.9 hr., the first failure in the work here reported occurred in 181 hr., and the longest life was 539 hr. The creep

Forged Blades . . .

rates of the present blades were lower than those of the earlier blades. About two-thirds of the failures originated at the trailing edge of the blade, and one-third at the leading edge.

Six blades, including those giving the shortest and longest service, were subjected to metallographic tests. Those with the shorter service lives had coarser and less uniform grain sizes. They also showed more oxide penetration from the surface. Defects such as microvoids, slag inclusions, removal of carbide by oxidation, and fatigue cracks were found near the surface of all the specimens examined. Carbide precipitation and agglomeration increased with the length of service. The inferior blades of the older production showed coarser and less uniform microstructures and more carbide precipitation and oxide penetration.

Twelve specimens for stress-rupture tests were cut from blades and tested at 1500° F. and 20,000 psi. At this stress the time for rupture ranged from 89.5 to over 1346 hr. Fewer grains coarser than A.S.T.M. No. 6, and more carbides, were noted in the specimens of longer life (the carbon contents are not given). No difference in dirtiness or porosity was found. Carbide precipitation increased with longer test periods. Agglomeration of the carbides did not weaken the alloy appreciably.

The first blade failure at 181 hr. with 21,500 psi. stress at 1500° F. agrees well with the 100-hr. rupture strength of 23,000 psi. reported elsewhere for S-816 bar stock at 1500° F. But the extreme scatter of blade lives and stress-rupture data precludes useful correlations. Blade failures in an engine may be expected to follow each other quite rapidly once they have started, making individual blade replacements relatively useless. The scatter of results was not explained by any structural features found in this work, and it is concluded that variables in fabricating methods must be the chief cause.

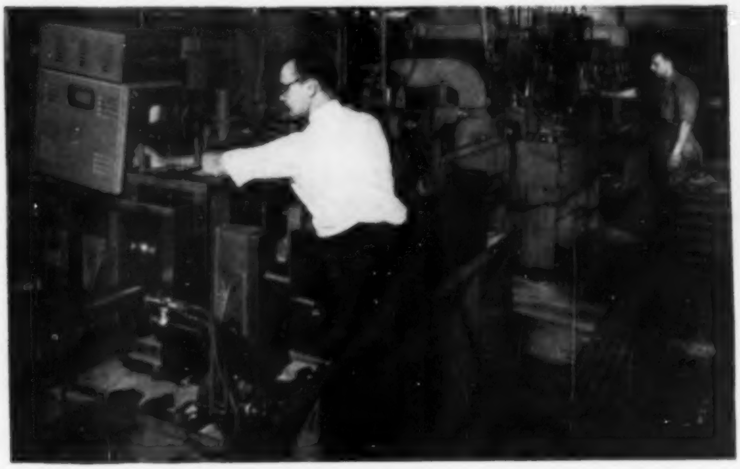
(A variation in carbon content within the range of 0.32 to 0.42% is not discussed as a possible cause of differences in properties, but such a variation would have been quite important in steel.)

G. F. Comstock

Sperry

ultrasonic inspection news

AUTOMATIC INSPECTION AND CONTROL ON CONTINUOUS PRODUCTION LINE



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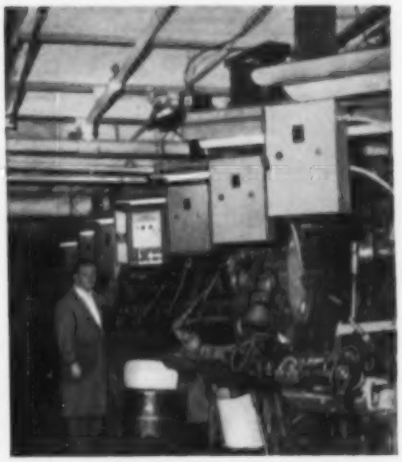

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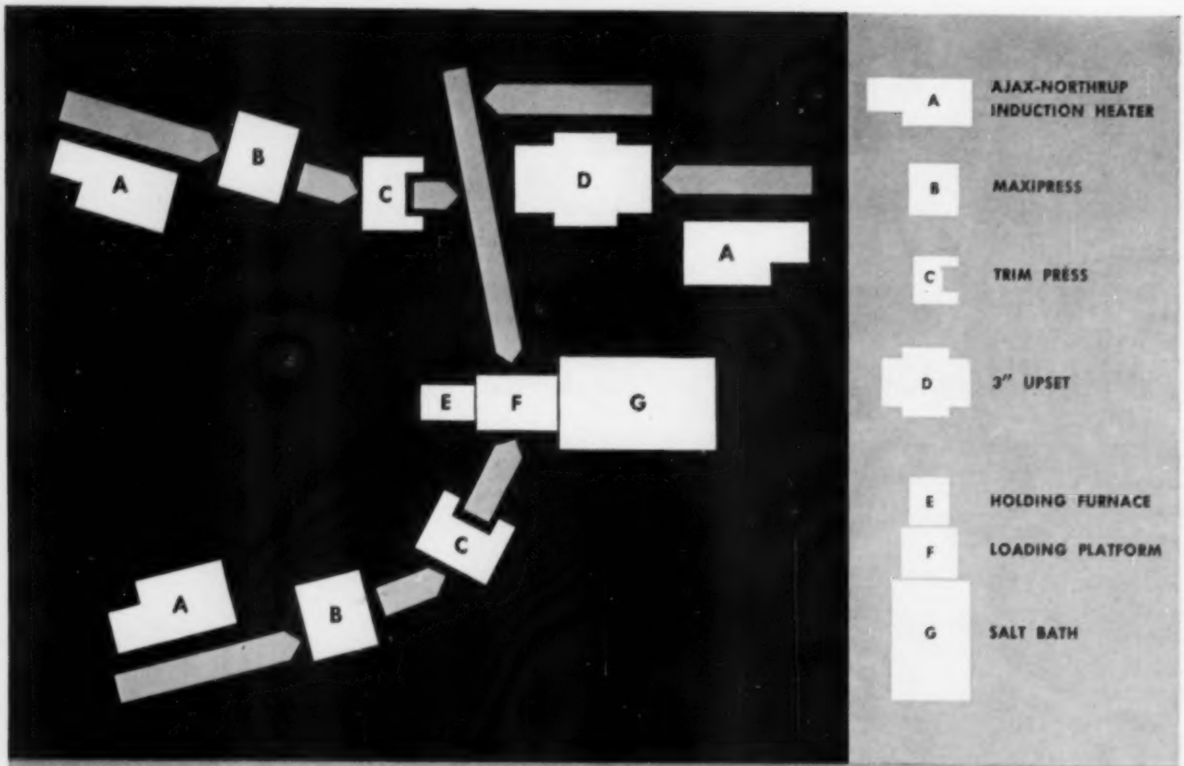

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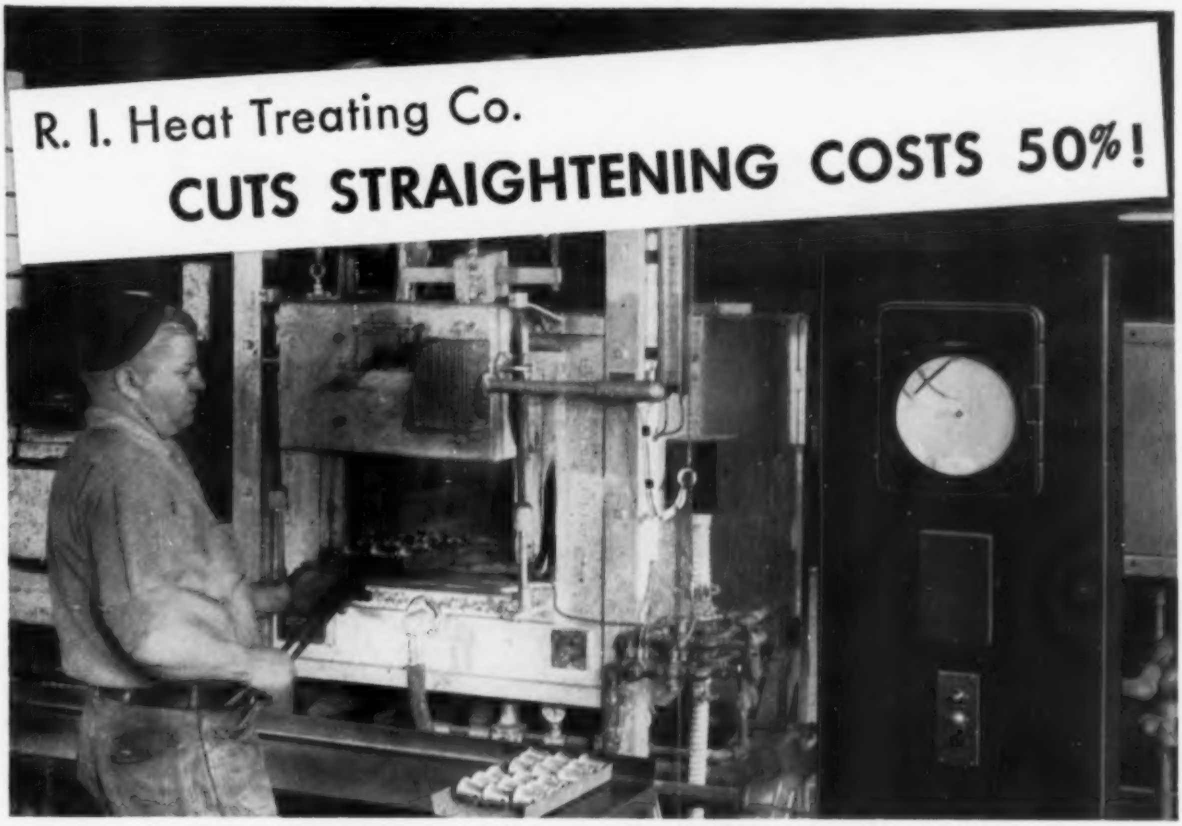

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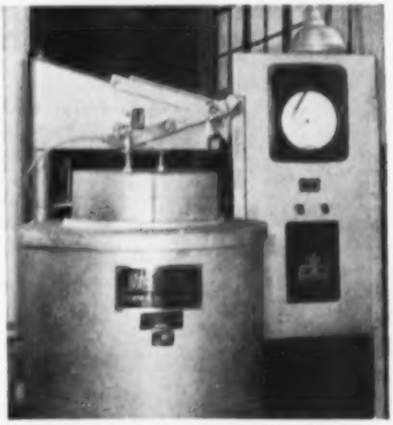

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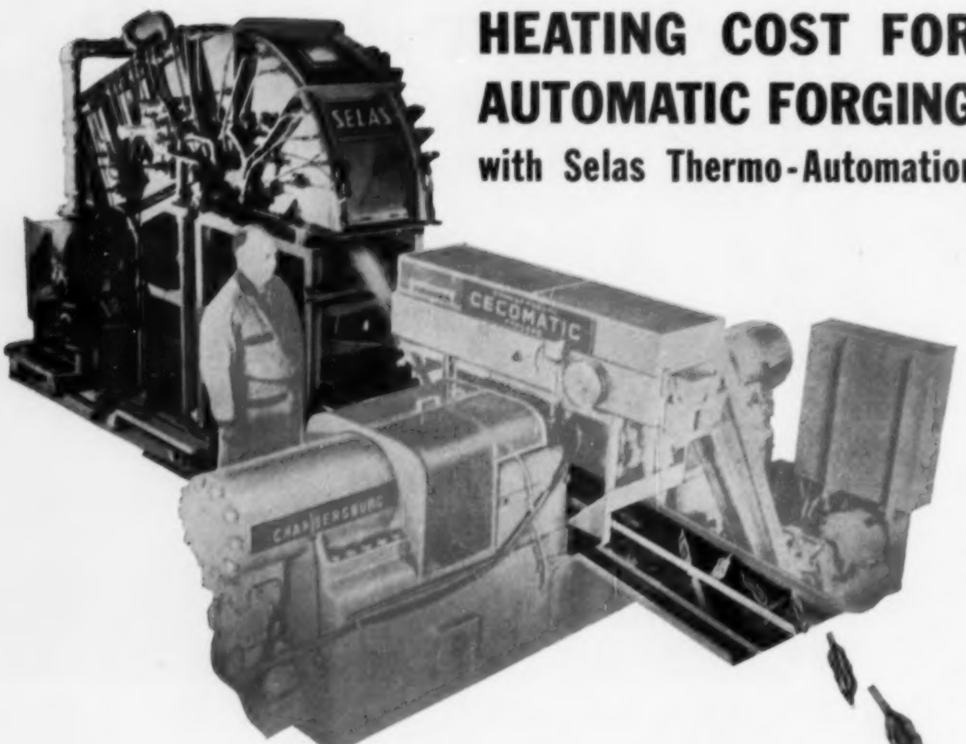

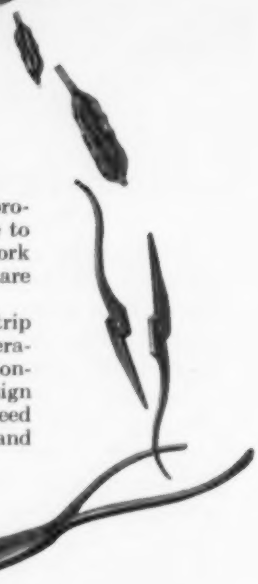

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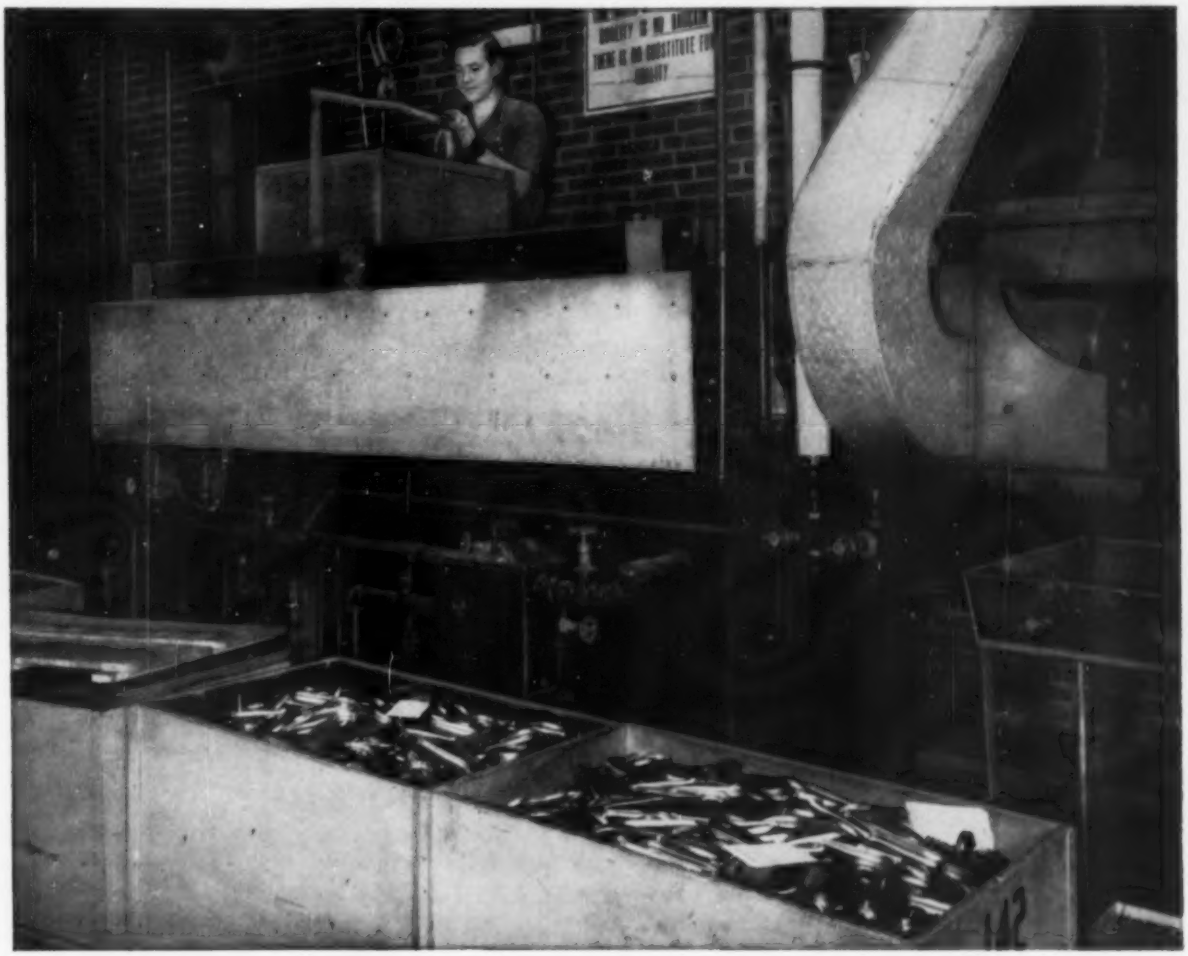

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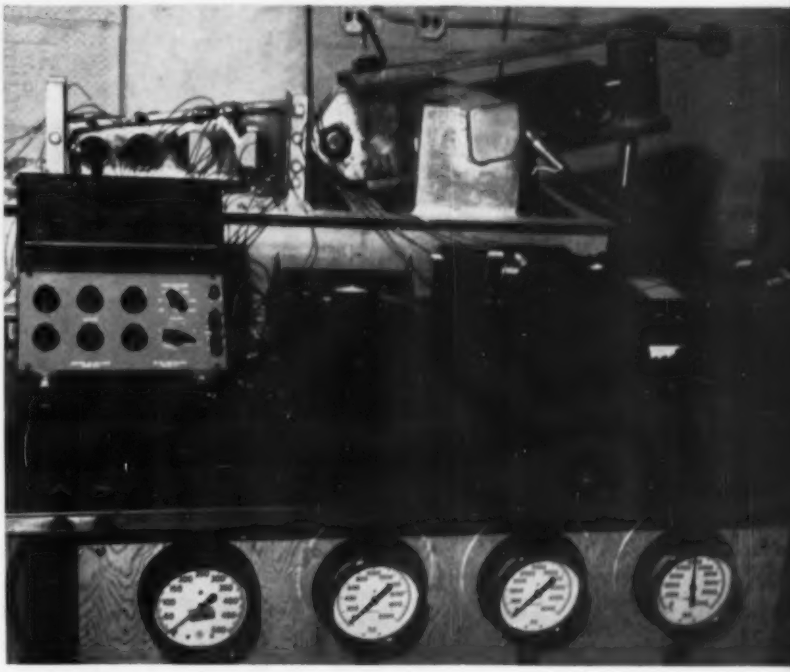

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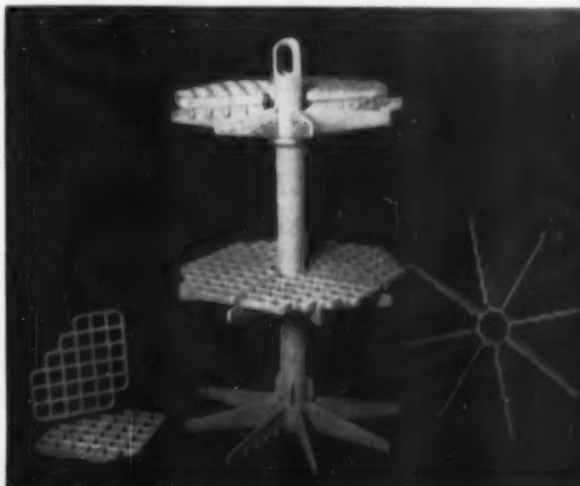

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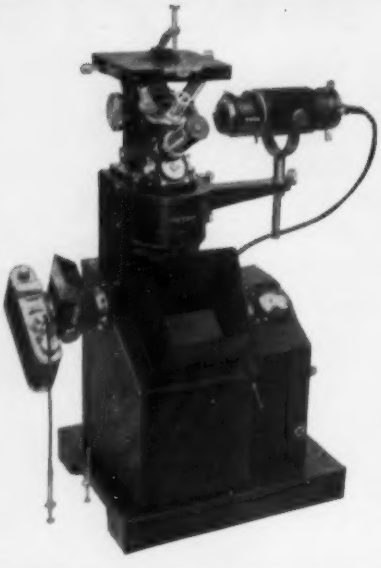

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- For visual observation, measurement, and photography of both opaque and transparent specimens.
- Bright field, dark field, and polarized illumination.
- Revolving nosepiece with 5 objective lenses, 4 photographic eyepieces, 3 visual eyepieces. Coated optics. Magnification range: 25-2000X.
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- Many other important features and accessories including calibrated polarizing apparatus, filters, micrometer eyepieces, film holders, etc. Cabinet.
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- illuminator mounts substage for transparent specimens.
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- coated optics.
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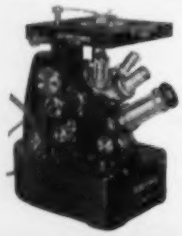

UNITRON Model MEC

is of the inverted type and designed for visual observation of metals, ores, minerals, etc. It includes many of the features of the Model U-11 Metallograph which are connected with visual observation of opaque specimens. 25-1500X.

- transformer built into microscope base.
- vertical illuminator with iris diaphragm.
- coarse and fine focusing.
- filters: polaroid, frosted, blue, green, yellow.
- large mechanical stage with graduated circular rotatable stage plate.
- calibrated polarizing apparatus.
- coated optics
- revolving nosepiece with objectives 5X, 10X, 40X, 100X oil.
- eyepieces: P5X, Micrometer 10X, K15X.

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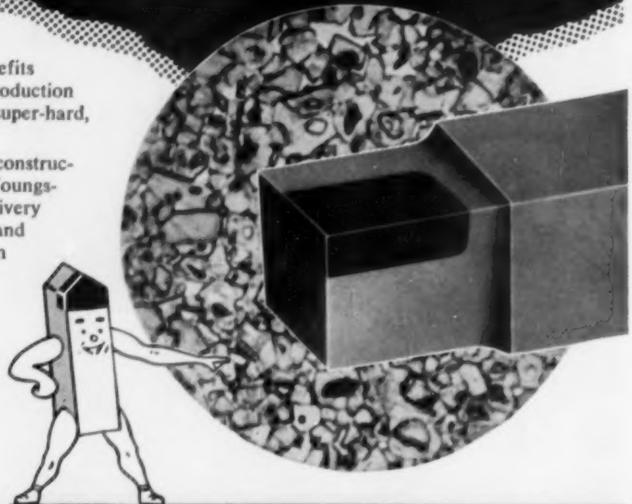

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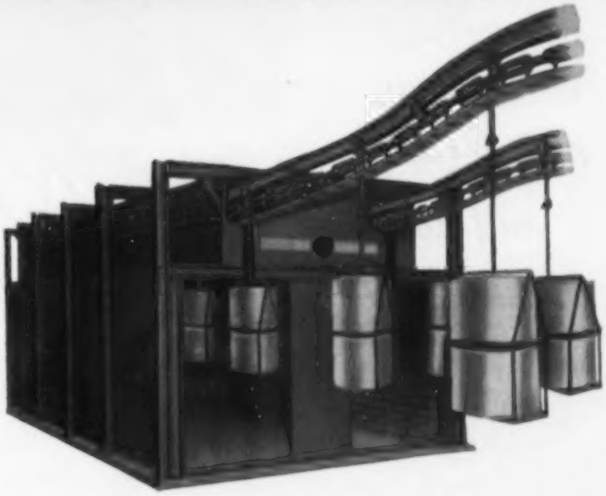

Fahralloy Burning Tools "carry the load" through this G-E furnace at Appliance Park, Louisville, for firing of the porcelain enamel.

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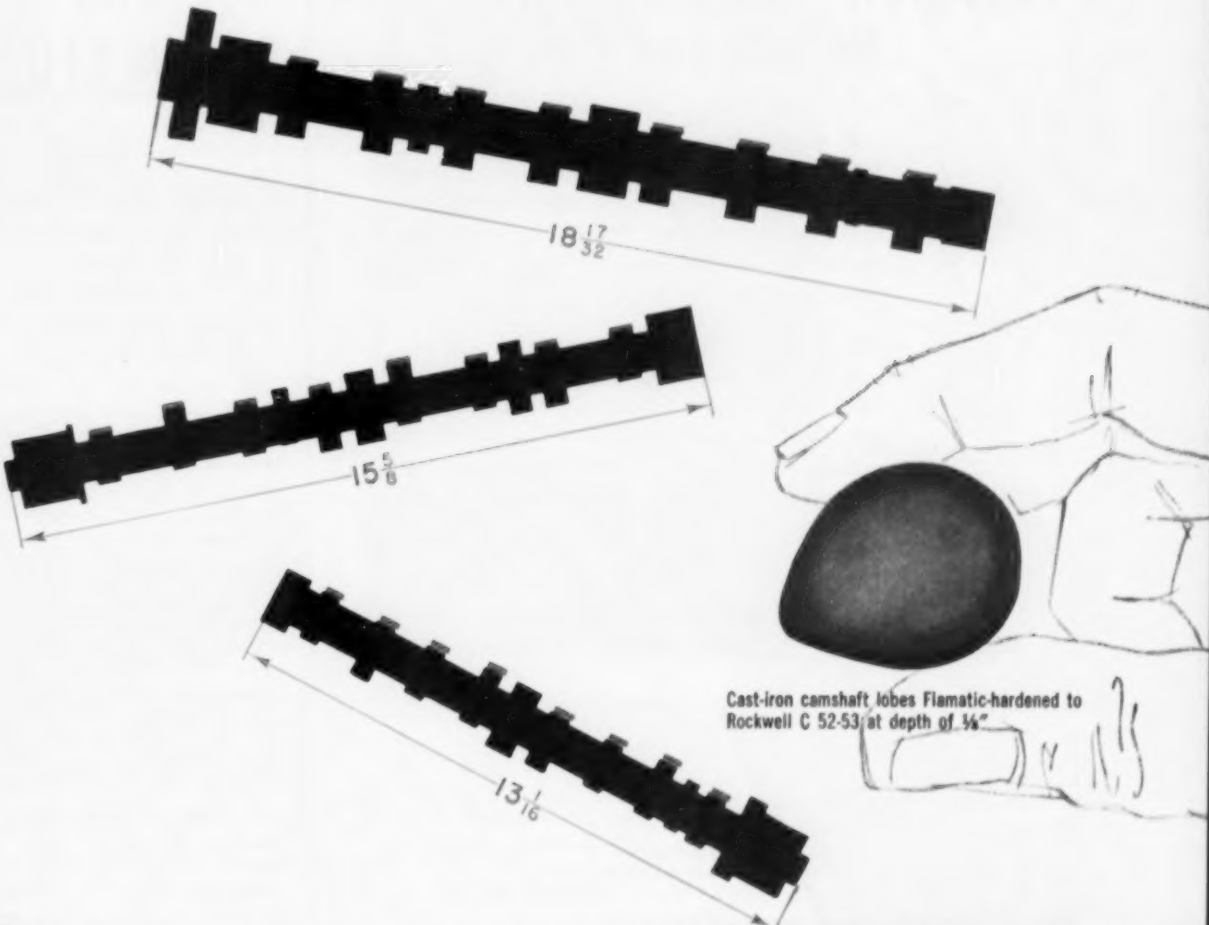
1 flamatic hardens 3 different camshafts



Cast-iron camshaft lobes Flamatic-hardened to Rockwell C 52-53 at depth of ⅛"

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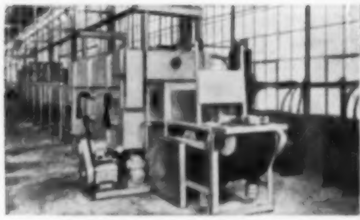
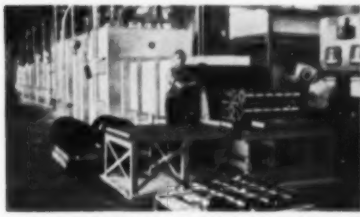


EF belt conveyor furnace bright annealing, coiled alloy steel and non-ferrous wire.

EF continuous roller rail pusher furnace, bright anneals large reels and coils of wire.

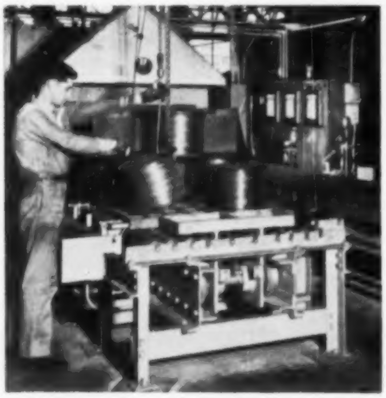
designed engineered and *Specially Built*



This furnace bright anneals wire on reels, spools, and coiled. Capacity 4000 lbs. per hr.

Stainless steel wire is bright annealed continuously in these EF multiple tube furnaces.

to meet the WIRE INDUSTRY'S requirements



Charging end of EF special atmosphere bulkhead pusher furnace; bright anneals copper and copper-weld wire and clean anneals brass wire. Capacity 4000 lbs. per hr.

We build production furnaces for heat processing all kinds of wire, rod, or other products—in any shape or form.

Years of practical experience in designing and building successful heat treating equipment for the wire industry enable us to furnish the best type of equipment for any purpose—and to produce the results required.

Shown here are 8 more production installations we made in prominent wire plants. We receive many repeat orders.

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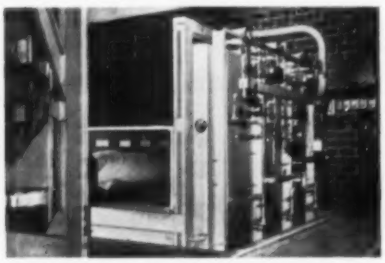
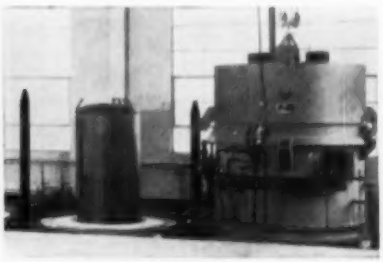


EF direct gas fired, single end, forced circulation hearth type annealing furnace with gantry crane for handling large coils of cupro nickel wire and brass rod.



EF direct gas fired bell type furnace with retorts and 4 forced circulation bases, used for bright annealing both ferrous and non-ferrous flat coiled wire.

EF special atmosphere continuous bright annealing furnace in which the wire is conveyed through the various zones on two parallel rows of bulkhead type trays.